Reconnaissance Report

Hopkinton Everett Lakes Hydropower Study New Hampshire

US Army Corps of Engineers
New England Division

APRIL 1983

HYDROPOWER STUDY

HOPKINTON-EVERETT LAKES
NEW HAMPSHIRE

RECONNAISSANCE REPORT

APRIL 1983

U.S. Army Engineer Division, New England
424 Trapelo Road
Waltham, Massachusetts 02254

FOREWORD

This report presents the results of a reconnaissance study of the feasibility of adding hydropower facilities at two Corps structures referred to as the Hopkinton-Everett Lakes flood control/recreation project located on the Contoocook and Piscataquog Rivers in the counties of Merrimack and Hillsboro, New Hampshire.

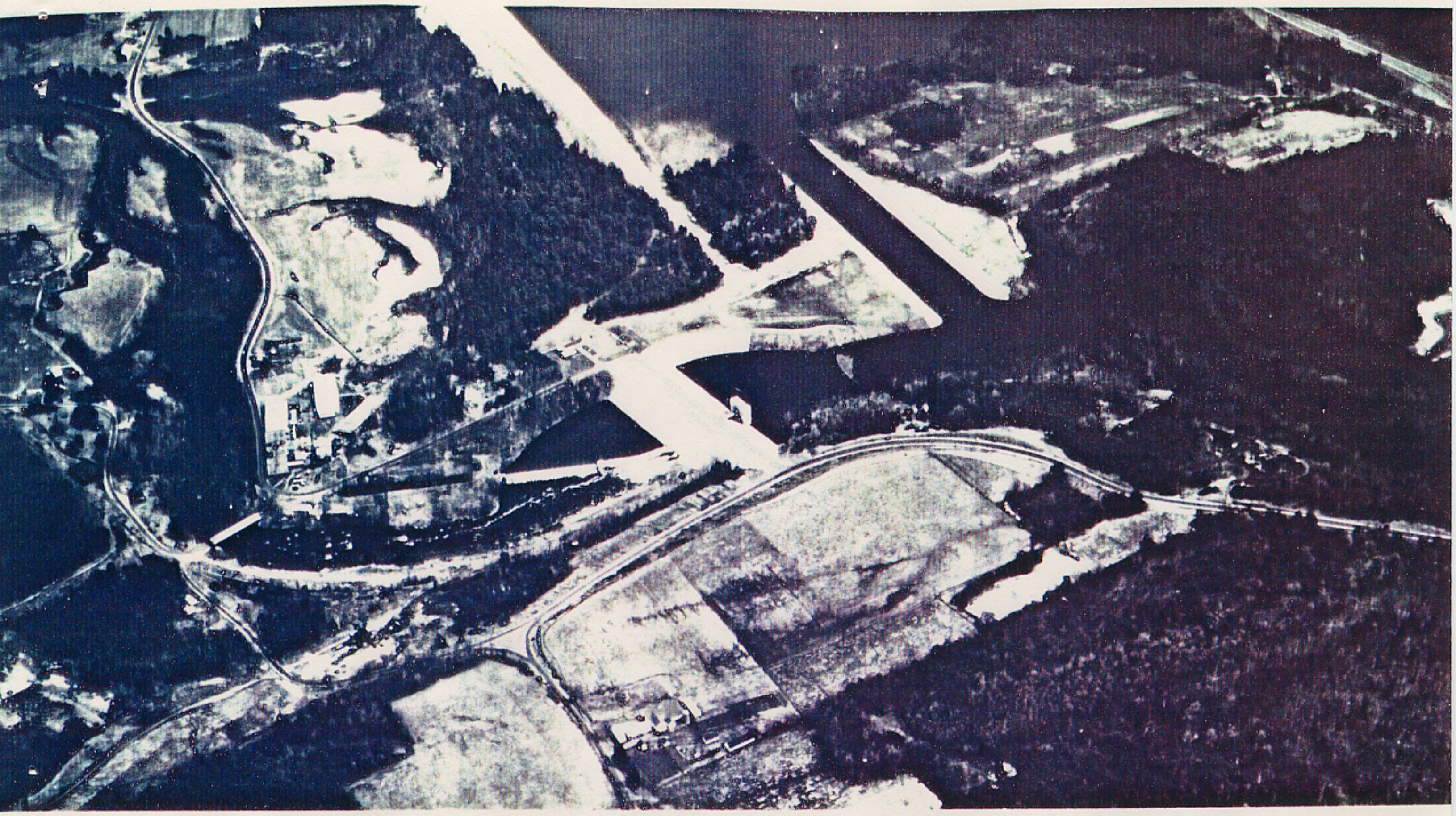
Since water rights at the Hopkinton site up to the permanent pool are owned by others and raising of the permanent pool for hydropower would have a negative water quality impact on Elm Brook pond, plans for hydropower development at Hopkinton were not evaluated.

Two alternatives for developing hydropower at Everett Lake were formulated and evaluated. Alternative 1 involves raising the permanent pool 30 feet and installing a 350 kW generating unit in a powerhouse located at the downstream toe of the dam. This alternative although capable of generating 1,310,000 kWh of energy was found not to be economically justified.

Alternative 2 was formulated utilizing a new concept of hydrogeneration and recently developed equipment. This alternative involves installing two submersible turbine-generator units in the recreational weir upstream of the dam. This alternative would not require any changes in the elevation of the existing pool and is capable of generating 435,600 kWh annually. The benefit to cost ratio of Alternative 2 was determined to be 1.24 to 1 and therefore the addition of submersible hydroelectric generating facilities is economically justified and merits further consideration.

The development of submersible turbine-generator equipment allows the formulation and evaluation of an additional alternative that was not available some years ago. This equipment is not suited for installation at all sites since it is designed primarily for low flow/low head conditions. Where favorable conditions exist, use of submersible units could allow hydropower development of a site that might not otherwise be economically justified by other types of hydrogenerating equipment.

The hydraulic, hydrologic and reservoir regulation studies and design and cost estimates performed for this study were conducted at a level of detail appropriate to a reconnaissance investigation. Detailed studies of formulation, design and cost estimating of additional plans of development, a determination of social and environmental acceptability, environmental assessments and marketing analysis will be conducted during the feasibility study stage which will be initiated after this report is approved and funded.



HOPKINTON DAM

EVERETT DAM

FIGURE 1

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I. INTRODUCTION

Purpose and Authority

This is a reconnaissance report on the feasibility of adding hydropower facilities at the Corps of Engineers "Hopkinton-Everett Lakes flood control project. The project is located in the State of New Hampshire within the towns of Hopkinton, Dunbarton, Henniker and Weare." Authority for this study is contained in Section 216 of Public Law 91-611 (the River and Harbor Act of 1970):

> Sec. 216. The Secretary of the Army, acting through the Chief of Engineers, is authorized to review the operation of projects the construction of which has been completed and which were constructed by the Corps of Engineers in the interest of navigation, flood control, water supply, and related purposes, when found advisable due to the significantly changed physical or economic conditions, and to report thereon to Congress with recommendations on the advisability of modifying the structures to their operation, and for improving the quality of the environment in the overall public interest.

Scope of Study

The principal thrust of this reconnaissance effort is to determine whether hydropower development appears to be feasible at Hopkinton-Everett Lakes. Due to funding limitations, baseline environmental, recreational, social and cultural information presented in this report was taken from previously published reports. Also, due to funding constraints, plan formulation activities were limited and potential environmental impacts have not been identified.

Study Participants and Coordination

This study was conducted by the New England Division, Corps of Engineers. There was no formal study participation or coordination with any State agency or the public. The Federal Energy Regulatory Commission (FERC) provided information which was used in the preparation of this report.

The Report and the Study Process

This reconnaissance report is the product of the first of three study stages which the Corps uses for planning potential projects. In subsequent study stages alternative plans will be formulated, developed, and evaluated: an implementable plan may be identified and submitted to Congress for authorization and construction.

The multiobjective planning framework utilized by the Corps is designed to insure that a complete and systematic evaluation is accomplished. Problems, needs, concerns and opportunities are identified and addressed. Plans are formulated and evaluated and impacts are assessed. Public input is sought throughout the study and efforts are made to keep the public informed of the study progress and significant findings. The approaches used for this study are consistent with the President's Water Resources Council's "Principles and Standards" and the National Environmental Policy Act of 1969.

As the study progresses, in depth data will be developed to allow increasingly detailed evaluation and assessment of alternatives, until it is possible to identify the best alternatives from both environmental and economic viewpoints. Ultimately, using the study findings and public involvement, a plan judged to be in the best public interest may be identified.

Other Studies

EHC Hydro Associates of Boston, Massachusetts owns the water rights at Hopkinton Dam to elevation 380 feet NGVD, which is the permanent pool maintained at that site. This pool is maintained by the Hoague-Sprague Dam, which is located immediately downstream of Hopkinton Dam. EHC Hydro was issued an exemption from licensing by the Federal Energy Regulatory Commission (FERC) for development of a hydroelectric generating facility located downstream of Hopkinton Dam that is designed to utilize a power pool with an elevation of 380 feet NGVD.

Water Power Development Corporation of New Hampshire held FERC preliminary permit #3426 on Hopkinton-Everett Lakes. The permit was surrendered in February 1982. There are currently no other known hydropower studies at Hopkinton-Everett Lakes.

In December 1976 the Corps of Engineers prepared an Environmental Assessment of the operations and maintenance of Hopkinton-Everett Lakes. In August 1977 the Corps completed its Merrimack River Basin Master Water Control Manual. And, in May 1978, the Corps released a design memorandum entitled "Master Plan for Recreation Resources Development, Hopkinton-Everett Lakes, New Hampshire." Several other design memoranda were prepared in the 1958-1959 time frame.

II. PROBLEM IDENTIFICATION

National and Regional Objectives

The primary purpose of the hydropwer addition under consideration is to reduce regional (and national) dependence on oil for electrical energy generation. Currently, about 60 percent of New England's electrical energy is produced at oil-fired generating plants. A hydropower addition to the Hopkinton-Everett project would displace oil-generated electrical energy, thereby reducing dependence on oil. Any hydropower plans developed would have to be technically, environmentally, economically and socially acceptable.

Existing Conditions in the Study Area

Physical Setting

Located in the Merrimack River Basin in central New Hampshire, Hopkinton-Everett Lakes is a flood control/recreation project owned and operated by the U.S. Army Corps of Engineers. A reservoir map showing the location of major project features is shown as Figure 2. The project straddles two watersheds, the Piscataquog and the Contoocook. Hopkinton-Everett Lakes consists of Hopkinton Dam, Everett Dam, two spillways, four dikes and two canals. Hopkinton Dam is located on the Contoocook River about 8 miles west of Concord, New Hampshire in the town of Hopkinton (Merrimack County). Everett Lake and Dam is located on the Piscataquog River about 11 miles northwest of Manchester, New Hampshire in the town of Weare (Hillsboro County). The combined flood control reservoir, which has a surface area of about 103 square miles and a storage capacity of 157,300 acre-feet at spillway crest elevation, extends into the towns of Dunbarton (Merrimack County) and Henniker (Hillsboro County).

Pertinent data on the Hopkinton-Everett Lakes project is summarized in Table 1.

Hopkinton Dam and appurtenant structures include an earth dam, outlet works, concrete spillway, Canal No. 1, two earth dikes (H-2 and H-3), and reservoir storage for recreation and flood control. A general plan of the dam and outlet works is shown in Figure 3. The embankment consists of a rolled earth and rock section approximately 790 feet in length. The maximum height above streambed is 76 feet. The 24-foot top width accommodates New Hampshire Route 127. The top of the dam is at elevation 437 feet NGVD.

The outlet works at Hopkinton Dam, as shown in Figure 4, consists of an intake structure and gate tower on the upstream side of the dam, and three 11-foot square conduits, each controlled by two 6-foot wide x 12-foot high vertical lift gates with inverts at elevation 366. Two conduits, referred to as the "flood control" conduits, discharge into two 32 x 67 foot stilling basins and the Contoocook River. The third,

TABLE 1

PERTINENT DATA

HOPKINTON-EVERETT LAKES

	Hopkinton	Everett	Total
LOCATION	Contoocook River, Hopkinton, N. H.	Piscataquog River, Weare, N. H.	
DRAINAGE AREA	382 square miles*	64 square miles	446 square miles*
STORAGE USES	Flood control and recreation		
RESERVOIR STORAGE			
At Inlet Elevation (ft, msl)	366	325	-
Area (acres)	0	0	0
Acre-Feet	0	0	0
At Permanent Pool (ft, msl)	380	340	-
Area (acres)	220	130	350
Acre-Feet	700	1,000	1,700
Inches on Drainage Area	Less than 0.1	0.3	Less than 0.1
At Spillway Crest (ft, msl)	416	418	-
Area (acres)	3,700	2,900	6,600
Acre-Feet	70,100**	91,500**	161,600**
Inches on Drainage Area	3.4	26.8	6.8
EMBANKMENT FEATURES			
Type	Rolled earth fill with rock slope protection		
Length (feet)	790	2,000	
Top Elevation (ft, msl)	437	435	
Maximum Height (feet)	76	115	
Top Width (feet)	24	24	
Slopes	1 on 2.5	1 on 2 to 1 on 2.5	
SPILLWAYS			
Type	Concrete ogee weir	Concrete ogee weir	
Crest Length (feet)	300	175	
Crest Elevation (ft, msl)	416	418	
Location	1.5 miles east of dam	Left abutment	
SDF Surcharge (feet)	14	12	
SDF Discharge (cfs)	59,700 (spillway) 13,200 (conduit)	28,500 (spillway 4,600 (conduit)	
SDF Peak Inflow (cfs)	135,000	68,000	
OUTLET WORKS			
Type and Number	3 square conduits (2 flood control, 1 forebay)	1 circular conduit	
Conduit Inside Dimensions	11 feet x 11 feet	8 feet diameter	
Conduit Lengths (feet)	Flood control 124, forebay 128	350	
Invert Elevation (feet, msl)	366	325	
Service Gates	6 @ 12 feet high x 6 feet wide (4 flood control, 2 forebay)	3 @ 6 feet high x 3.5 feet wide	
Emergency Gates	1 @ 12 feet high x 6 feet wide	None	
Downstream Channel Capacity (cfs)	7,000	1,500	
Maximum Discharge Capacity (spillway crest elevation)	14,000 cfs	2,900 cfs	
Stilling Basins			
Number	2***	1	
Size	32 feet wide x 67 feet long	30 feet maximum width x 50 feet length	

DIKE FEATURES

	H-2	H-3	P-1	P-2
Type	Compacted earth fill with rock slope protection			
Length (feet)	5,220	4,400	4,050	2,630
Top Elevation (ft, msl)	435	435	435	435
Maximum Height (feet)	66	67	50	30
Conduits	Dike P-1 only: Inlet elevation 384.6 feet msl Dimensions: Length 220, width 4 feet, height 5 feet			

	Hopkinton	Everett	Total
CANALS			
Designation	Canal No. 1	Canal No. 2	
Bottom Width (feet)	120	160	
Length (feet)	4,000	10,400 (from North Weir to South Weir)	
Side Slopes	1 on 2.5 to 1 on 3	1 on 2.5	
LAND ACQUISITION			Total Acres
Fee Taking Elevation (ft, msl)	410	400	7,910 Fee
Flowage Easement Elevation (ft, msl)	420	420	2,024 Easement
Downstream Flowage Easement (cfs)	7,000	1,500	
MAXIMUM POOL OF RECORD			
Date	April 1969	April 1969	
Elevation (ft, msl)	405.0	397.1	
Percent of Flood Control Storage	0	0	47
UNIT RUNOFF			Both Projects
One Inch Runoff (acre-feet)	-	-	23,760 (net)
OPERATING TIME			
Open/Close All Gates	15 minutes	20 minutes	
PROJECT COST (Through FY 1974)	-	-	$21,360,000
DATE OF COMPLETION	October 1962	December 1961	-
MAINTAINED BY	New England Division, Corps of Engineers		

* Net drainage area - does not include 44 square miles controlled by MacDowell Dam

** Net (flood control) above permanent pool

*** For flood control conduits; forebay conduits empties into forebay pool (w.s. elevation = 380 feet)

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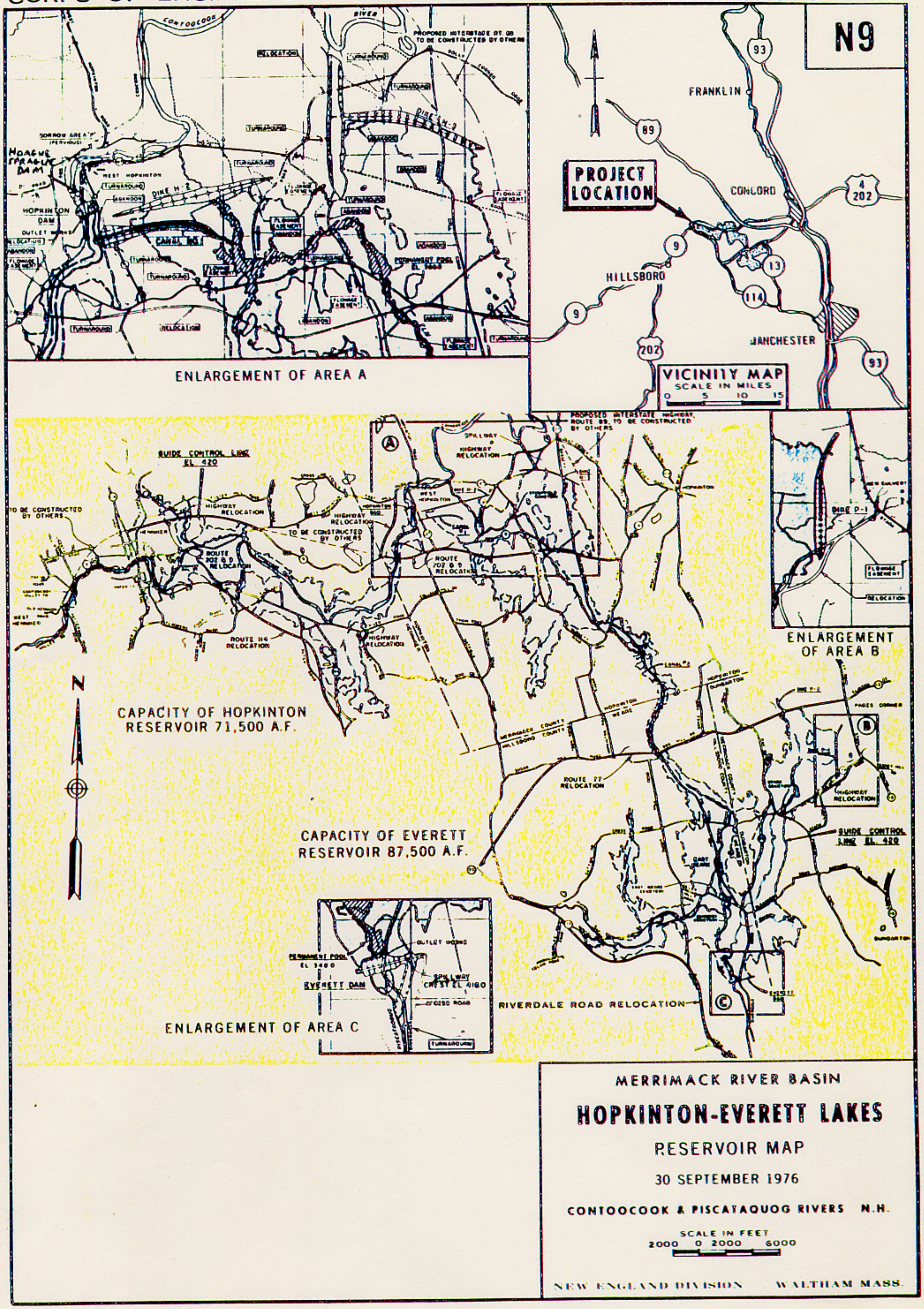


FIGURE 2

The water equivalent of the snowpack usually reaches a maximum of about 5 inches in the month of March with a maximum recorded water equivalent of 11 inches over the past 19 years.

Average annual runoff at Hopkinton Dam is approximately 22 inches, which is equivalent to an average runoff rate of about 1.6 cfs per square mile of drainage area. The average flow at the dam is about 700 cfs. The average annual runoff at Everett Dam is approximately 20 inches or about 50 percent of the annual precipitation, equivalent to an average runoff rate of about 1.5 cfs per square miles of drainage area. The average flow at the dam is about 96 cfs.

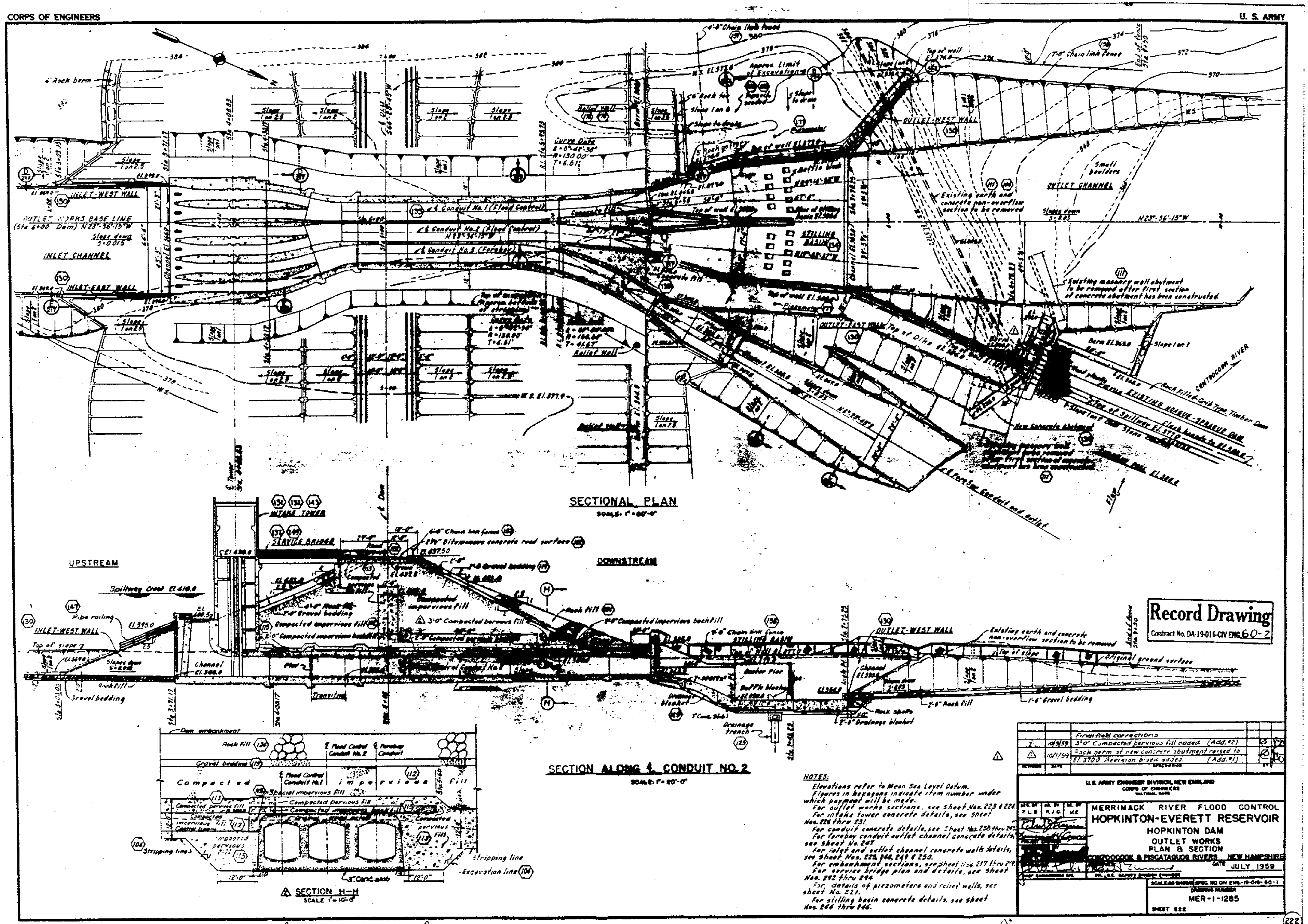
The Contoocook and Piscataquog drainage basins are underlain by igneous and metamorphic bedrock which was later sculptured by glacial scouring and the erosive action of surface waters. A veneer of relatively recent glacial till and stratified deposits is now to be found in most places overlying topography earlier formed by the structural evolution of the region and by subsequent geomorphological processes. The structural framework of the area conforms with that of the Appalacian regional province in which topographic highs and lows generally trend in a north-northeasterly and south-southwesterly direction. The Contoocook River valley above Henniker generally conforms to the controls imposed by the structure of the bedrock. The glacial and surficial alluvial deposits are thickest in the lower elevations of the region where streams and ponds exist.

No mineral deposits of any significant value, except sand and gravel, have been found in the project area.

The soils of the area are mostly derived from the underlying granites, gneisses and schists, more or less modified by the size-sorting of glacial meltwaters and the more recent sedimentation activities of streams. These soils are generally assigned to the podzolic category of soils, though some areas in the bottom lands have alluvial and humic soils.

Elevations in the close vicinity of the project area vary only moderately, ranging from about 1400 feet NGVD to 340 feet NGVD. The area might be described as gently rolling with rounded hills and rather broad valleys. A topographic map of the project area is shown on Figure 9.

The interspersion of woodland, agricultural land and brush or fallow land reflects both the variations in topography and the changes in land use over periods of time. Woodland comprises nearly 50 percent of the project area and various species of northern hardwoods are mixed with pine and hemlock. A portion of the agricultural land, which made up 10 percent of the project area when construction work first began, is leased as pasture, hay and corn fields to local farmers. The remaining agricultural land, now abandoned, is fast reverting to brushland as it is being invaded by various pioneer species such as aspen and gray birch. Some fields,



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SECTIONAL PLAN
SECTION ALONG ℄ CONDUIT NO. 2
SCALE: 1" = 20'-0"
SECTION H-H
SCALE 1" = 10'-0"
UPSTREAM
DOWNSTREAM
INTAKE TOWER
SERVICE BRIDGE
INLET CHANNEL
INLET-WEST WALL
INLET-EAST WALL
OUTLET WORKS BASE LINE
OUTLET-WEST WALL
OUTLET-EAST WALL
OUTLET CHANNEL
STILLING BASIN
CONTOOCOOK RIVER
EXISTING HOAGUE-SPRAGUE DAM
Record Drawing
Contract No. DA-19-016-CIV ENG 60-2
NOTES:
Elevations refer to Mean Sea Level Datum.
Figures in hexagons indicate item number under which payment will be made.
For outlet works sections, see Sheet Nos. 223 & 224.
For intake tower concrete details, see Sheet Nos. 226 thru 231.
For conduit concrete details, see Sheet Nos. 238 thru 243.
For forebay conduit outlet channel concrete details, see Sheet No. 247.
For inlet and outlet channel concrete walls details, see Sheet Nos. 225, 248, 249 & 250.
For embankment sections, see Sheet Nos. 217 thru 219.
For service bridge plan and details, see Sheet Nos. 292 thru 294.
For details of piezometers and relief wells, see Sheet No. 221.
For stilling basin concrete details, see Sheet Nos. 244 thru 246.
Final field corrections
2 10/9/59 3'-0" Compacted pervious fill added. (Add. #2)
1 10/1/59 Rock berm at new concrete abutment raised to El. 370.0 Revision block added. (Add. #1)
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
HOPKINTON DAM
OUTLET WORKS
PLAN & SECTION
CONTOOCOOK & PISCATAQUOG RIVERS NEW HAMPSHIRE
JULY 1959
MER-1-1285
SHEET 222

FIGURE 4

referred to as the "forebay" conduit, discharges directly into the forebay pool, which is controlled by the Hoague-Sprague Dam.

The chute spillway, located at the west end of dike H-3, consists of a discharge chute excavated in rock. The spillway has a crest length of 300 feet, a crest at elevation 416 NGVD and discharges into the Contoocook River.

Canal No. 1 connects the Contoocook and Elm Brook pools. The invert of the main channel is at elevation 382, with a pilot channel at invert elevation 372. Dike H-2, with a length of 5,220 feet and a maximum height of 77 feet above the streambed, is located on Elm Brook above its junction with the Contoocook River. Dike H-3, with a length of 4,400 and a maximum height of 66 feet, is located between the Elm Brook and Contoocook River valleys.

Everett Dam and appurtenant structures include an earth dam, concrete spillway, outlet works, and 2 earth dikes (P-1 and P-2). A general plan of the dam and appurtenant structures is shown in Figure 5. The dam consists of rolled earth fill with rock slope protection and is approximately 2,000 feet in length, with a maximum height of 115 feet above streambed. The top of the dam at elevation 435 feet NGVD.

The chute spillway, located in the left abutment of the dam, consists of a shallow approach channel, a concrete ogee weir and a discharge chute excavated in rock. The spillway has a crest length of 180 feet at elevation of 418 feet NGVD.

The outlet works, as shown in Figure 6, consist of an intake structure, gate tower on the upstream side of the dam and an 8-foot circular conduit. The intake end of the conduit contains three 3'-6" wide x 6'-0" high sluice gates, with invert at elevation 325. The conduit empties into a stilling basin, with a length of 50 feet and width of 30 feet.

Dike P-1 is located on Stark Brook and consists of a conduit and a rolled earth fill embankment with a length of 4,050 feet, a maximum height of 50 feet and the top at elevation 435 NGVD. Dike P-2 is constructed the same as dike P-1, except it does not have a conduit. It is located across a saddle separating the Piscataquog and Merrimack River valleys and consists of a rolled earth fill embankment with a length of 2,630 feet, a maximum height of 30 feet, and top at elevation 435 NGVD.

Canal No. 2 is about 10,400 feet in length and connects Hopkinton and Everett Lakes as shown on Figure 2. During moderate and major floods, when stages in the Elm Brook pool exceed elevation 401±, waters begin passing southward over the Sugar Hill roadway (North Weir) and into Drew Lake, which forms the upper portion of the canal. Flows continue southward through the man-made section of the canal from Drew Lake, and over the South (Choate Brook) Weir - crest elevation 400.75 feet. After passing over the South Weir, waters flow down Choate Brook into Everett Lake.

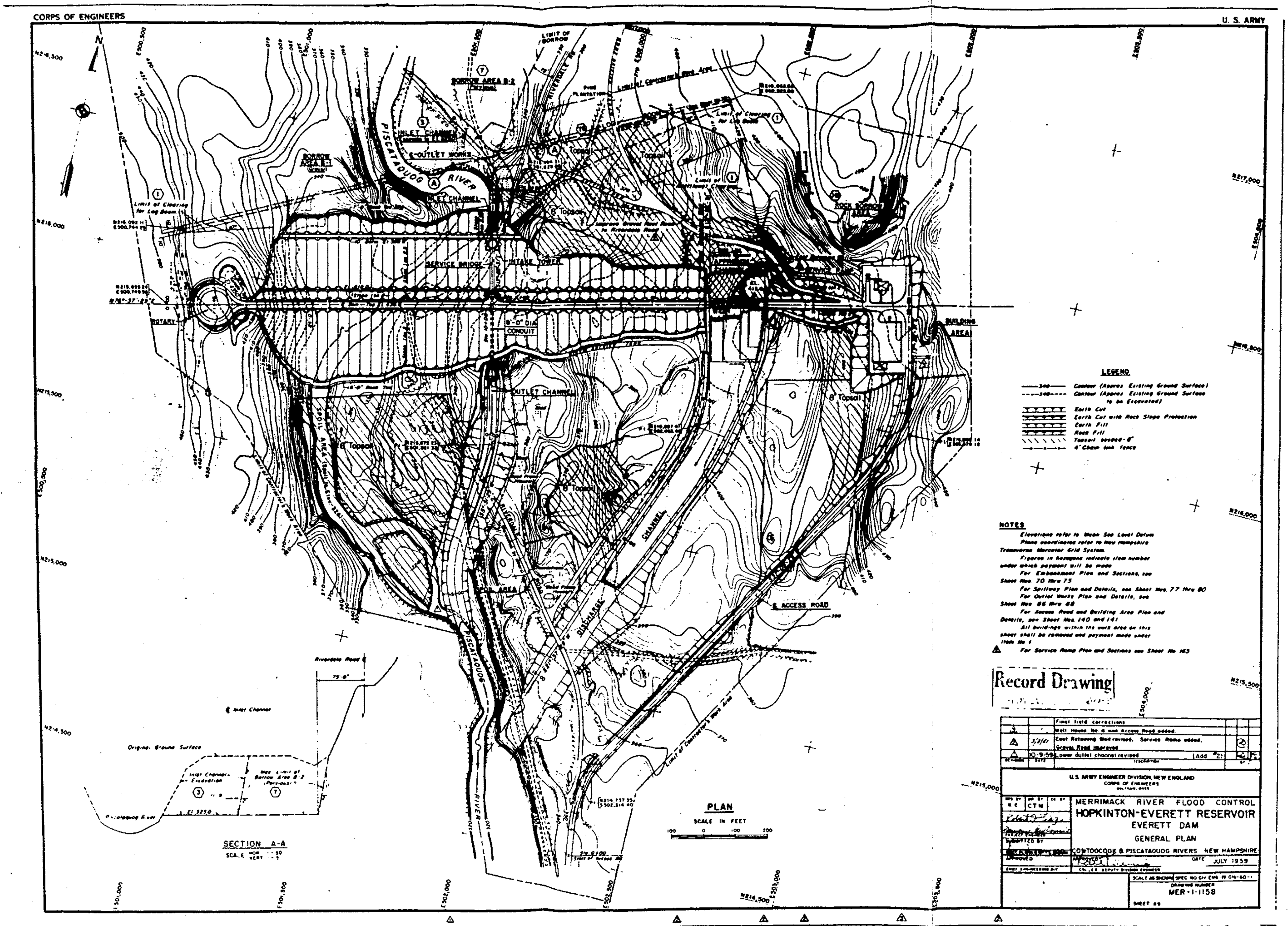

CORPS OF ENGINEERS
U. S. ARMY
BORROW AREA B-2
INLET CHANNEL
OUTLET WORKS
PISCATAQUOG RIVER
BORROW AREA B-1
ROCK BORROW AREA
SERVICE BRIDGE
INTAKE TOWER
ROTARY
8'-0" DIA CONDUIT
OUTLET CHANNEL
BUILDING AREA
8" Topsoil
SPOIL AREA
CHANNEL
DISCHARGE
ACCESS ROAD
PISCATAQUOG RIVER
LEGEND
Contour (Approx. Existing Ground Surface)
Contour (Approx. Existing Ground Surface to be Excavated)
Earth Cut
Earth Cut with Rock Slope Protection
Earth Fill
Rock Fill
Topsoil seeded - 8"
4' Chain link fence
NOTES
Elevations refer to Mean Sea Level Datum
Plane coordinates refer to New Hampshire Transverse Mercator Grid System
Figures in hexagons indicate item number under which payment will be made
For Embankment Plan and Sections, see Sheet Nos. 70 thru 75
For Spillway Plan and Details, see Sheet Nos. 77 thru 80
For Outlet Works Plan and Details, see Sheet Nos. 86 thru 88
For Access Road and Building Area Plan and Details, see Sheet Nos. 140 and 141
All buildings within the work area on this sheet shall be removed and payment made under Item No. 1
For Service Ramp Plan and Sections see Sheet No. 163
Record Drawing
Final field corrections
Well House No. 4 and Access Road added.
3/3/61 East Retaining Wall revised. Service Ramp added. Gravel Road improved
10-9-59 Lower outlet channel revised (Add #2)
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
EVERETT DAM
GENERAL PLAN
CONTOOCOOK & PISCATAQUOG RIVERS NEW HAMPSHIRE
DATE JULY 1959
DRAWING NUMBER
MER-1-1158
PLAN
SCALE IN FEET
SECTION A-A
Riverdale Road
Inlet Channel
Original Ground Surface
Piscataquog River

FIGURE 5

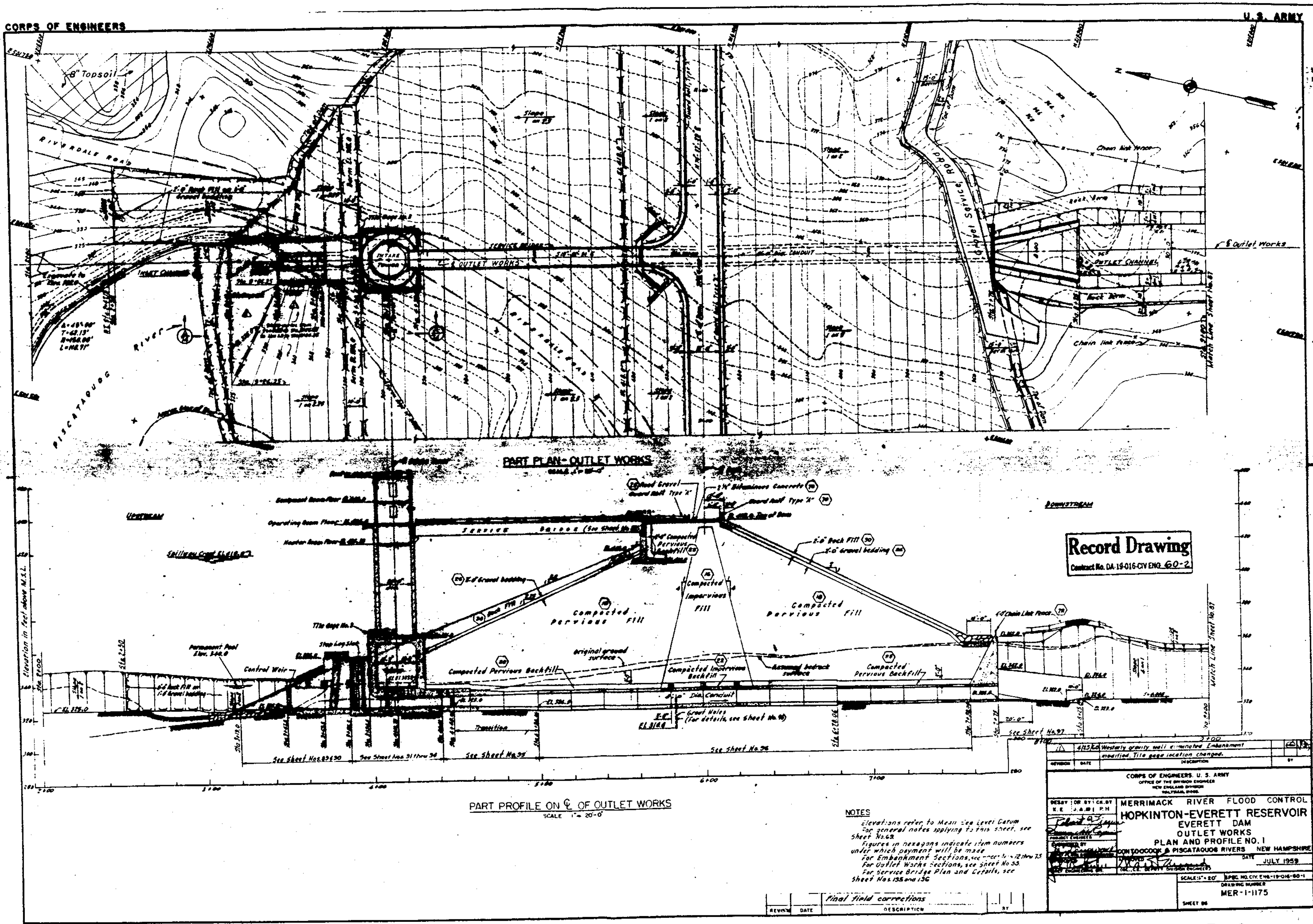

CORPS OF ENGINEERS
U. S. ARMY
8" Topsoil
Riverdale Road
Chain link fence
OUTLET WORKS
OUTLET CHANNEL
℄ Outlet Works
Match Line Sheet No. 87
Piscataquog River
PART PLAN - OUTLET WORKS
UPSTREAM
DOWNSTREAM
Record Drawing
Contract No. DA-19-016-CIV ENG 60-2
Compacted Pervious Fill
Compacted Impervious Fill
Compacted Pervious Backfill
Compacted Impervious Backfill
Original ground surface
Control Weir
Permanent Pool
Transition
See Sheet No. 95
See Sheet No. 96
See Sheet No. 97
Elevation in Feet above M.S.L.
PART PROFILE ON ℄ OF OUTLET WORKS
4/15/60 Westerly gravity wall eliminated. Embankment modified. Tile gage location changed.
REVISION DATE DESCRIPTION BY
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
WALTHAM, MASS.
MERRIMACK RIVER FLOOD CONTROL
HOPKINTON-EVERETT RESERVOIR
EVERETT DAM
OUTLET WORKS
PLAN AND PROFILE NO. 1
CONTOOCOOK & PISCATAQUOG RIVERS NEW HAMPSHIRE
JULY 1959
SCALE: 1" = 20'
SPEC. NO. CIV. ENG-19-016-60-1
DRAWING NUMBER
MER-1-1175
NOTES
Elevations refer to Mean Sea Level Datum
For general notes applying to this sheet, see Sheet No. 62
Figures in hexagons indicate item numbers under which payment will be made
For Embankment Sections, see sheets Nos. 12 thru 75
For Outlet Works Sections, see sheet No 53.
For Service Bridge Plan and Details, see Sheet Nos. 135 and 136
Final field corrections
REVISION DATE DESCRIPTION BY

FIGURE 6

During normal periods, a small box outlet with stop logs in the North Weir and a notch in the South Weir maintain a permanent water surface in Drew Lake and the canal at about elevation 400.4 to enhance aesthetics and recreation.

A small permanent pool is maintained at Hopkinton Lake at about elevation 380 by flashboards at the Hoague-Sparague Dam. These flashboards provide head necessary for hydropower production. This storage behind Hopkinton amounts to 700 acre-feet and covers an area of 270 acres. The Elm Brook recreation pool is maintained by a weir in the pilot channel of Canal No. 1.

At Everett, a permanent pool is maintained at about elevation 340 by a weir upstream of the center gate. This pool, maintained to enhance the recreation facilities, amounts to 1,000 acre-feet storage and covers 130 acres.

At Hopkinton Lake, reservoir lands have been purchased in fee to elevation 410, and flowage easements have been purchased to elevation 420. At Everett Lake, lands have been purchased in fee to elevation 400, and flowage easements have been purchased to elevation 420.

The Contoocook River rises at Contoocook Lake in Jaffrey, New Hampshire and follows a wandering course northeasterly for a distance of 66 miles, where it joins the Merrimack River at Penacook, New Hampshire. The Contoocook River has a drainage area of 766 square miles and a total fall of 760 feet. The drainage area above Hopkinton Dam is 426 square miles.

The Piscataquog River originates at Deering Reservoir in Deering, New Hampshire, and follows a sinuous course in its upper reach for a distance of over 8 miles to Weare Reservoir in Weare. Continuing in a southeasterly direction, the river follows an abruptly shifting course for a distance of about 16 miles to its confluence with the Merrimack River at Manchester, New Hampshire. The Piscataquog River has a drainage area of 220 square miles and a total fall of about 795 feet. The drainage area above Everett Dam is 64 square miles.

Figure 7 shows the entire Merrimack River Basin as well as the Piscataquog and Contoocook Basins. Profiles of the Merrimack River and its principal tributaries are shown in Figure 8.

The central portion of the Merrimack River Basin is characterized by moderately warm summers, when temperatures may infrequently rise above 100° Fahrenheit and relativley cold winters when temperatures may occasionally reach lows below minus 20 degrees, with an average annual temperature of about 46 degrees Fahrenheit. Average annual precipitation over the area is about 40 inches, rather uniformly distributed throughout the year. Much of the precipitation occurring during the winter months is in the form of snow with an average annual snowfall of about 63 inches.

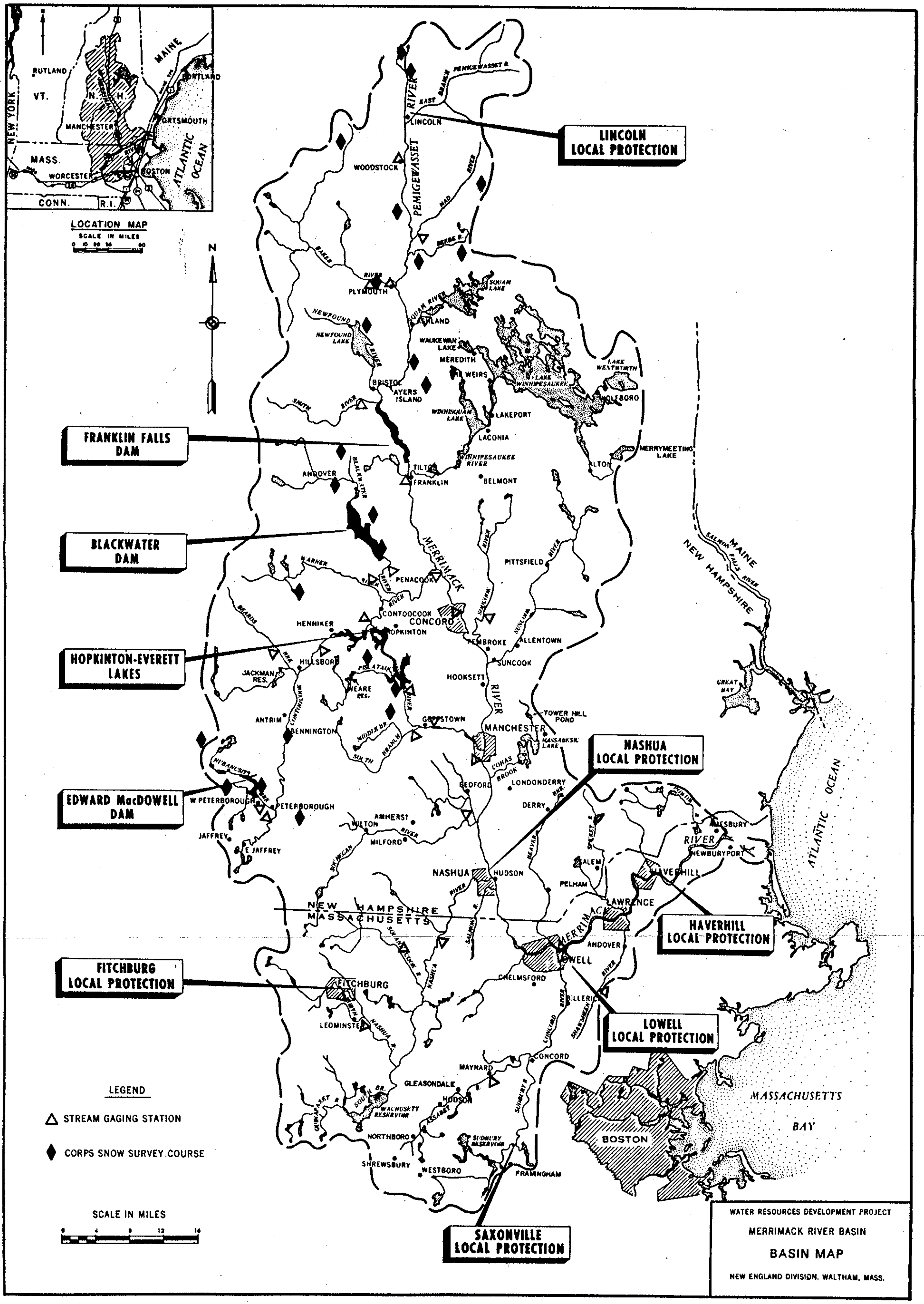
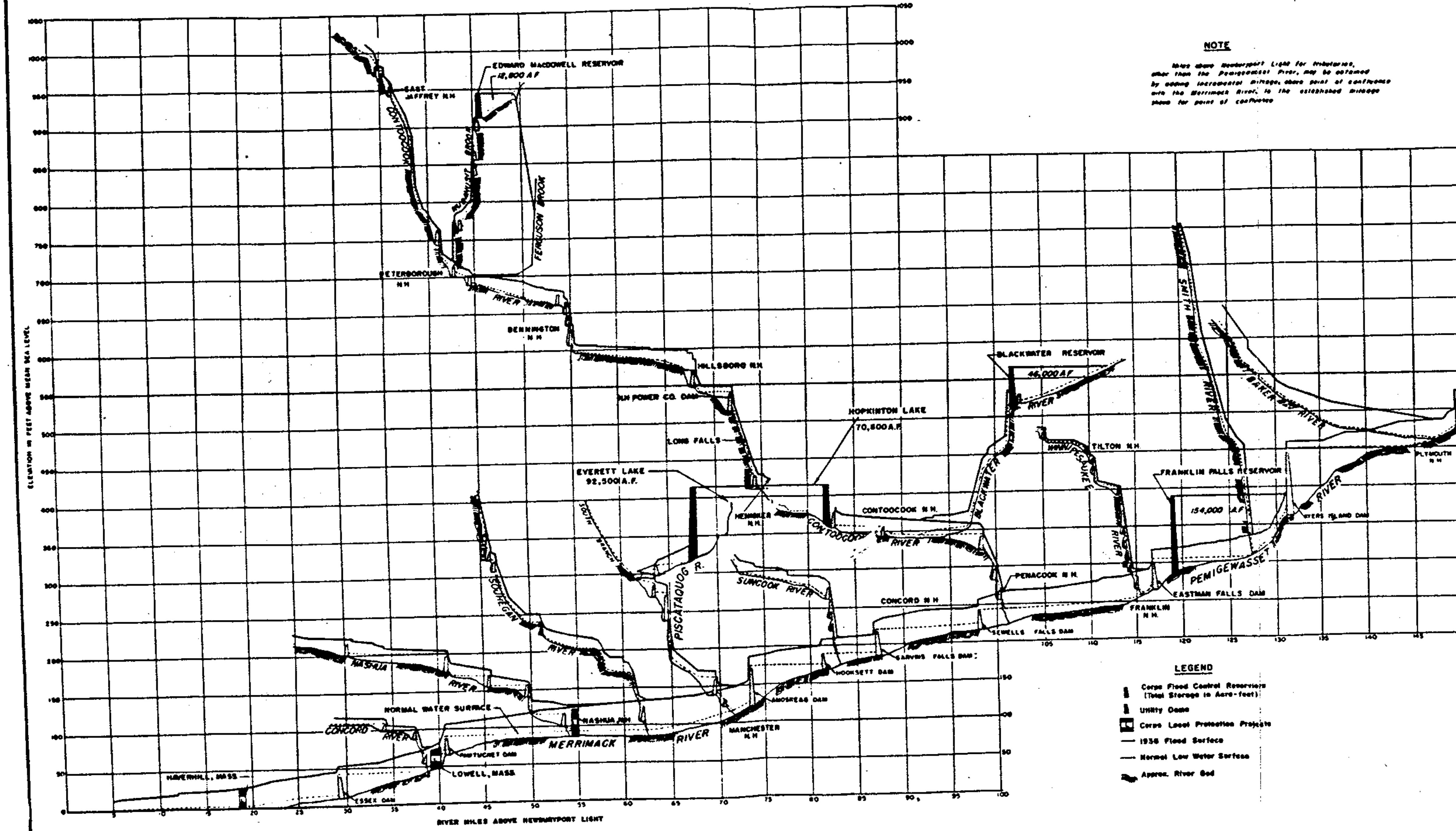

LOCATION MAP
SCALE IN MILES
RUTLAND
VT.
N. H.
MAINE
PORTLAND
MANCHESTER
PORTSMOUTH
NEW YORK
MASS.
WORCESTER
BOSTON
ATLANTIC OCEAN
CONN.
R.I.
N
LINCOLN LOCAL PROTECTION
FRANKLIN FALLS DAM
BLACKWATER DAM
HOPKINTON-EVERETT LAKES
EDWARD MacDOWELL DAM
NASHUA LOCAL PROTECTION
HAVERHILL LOCAL PROTECTION
FITCHBURG LOCAL PROTECTION
LOWELL LOCAL PROTECTION
SAXONVILLE LOCAL PROTECTION
PEMIGEWASSET RIVER
MERRIMACK RIVER
LINCOLN
WOODSTOCK
PLYMOUTH
ASHLAND
BRISTOL
AYERS ISLAND
MEREDITH
WEIRS
LAKEPORT
LACONIA
TILTON
FRANKLIN
BELMONT
ANDOVER
ALTON
WOLFEBORO
LAKE WINNIPESAUKEE
MERRYMEETING LAKE
PITTSFIELD
PENACOOK
CONTOOCOOK
CONCORD
HENNIKER
HOPKINTON
HILLSBORO
PEMBROKE
ALLENTOWN
SUNCOOK
HOOKSETT
GOFFSTOWN
MANCHESTER
TOWER HILL POND
ANTRIM
BENNINGTON
WEARE RES.
JACKMAN RES.
W. PETERBOROUGH
PETERBOROUGH
JAFFREY
E. JAFFREY
AMHERST
WILTON
MILFORD
BEDFORD
LONDONDERRY
DERRY
NASHUA
HUDSON
SALEM
PELHAM
HAVERHILL
AMESBURY
NEWBURYPORT
LAWRENCE
ANDOVER
NEW HAMPSHIRE
MASSACHUSETTS
LOWELL
CHELMSFORD
BILLERICA
FITCHBURG
LEOMINSTER
CONCORD
MAYNARD
GLEASONDALE
HUDSON
NORTHBORO
SHREWSBURY
WESTBORO
FRAMINGHAM
BOSTON
MASSACHUSETTS BAY
ATLANTIC OCEAN
MAINE
NEW HAMPSHIRE
GREAT BAY
LEGEND
STREAM GAGING STATION
CORPS SNOW SURVEY COURSE
SCALE IN MILES
0 4 8 12 16
WATER RESOURCES DEVELOPMENT PROJECT
MERRIMACK RIVER BASIN
BASIN MAP
NEW ENGLAND DIVISION, WALTHAM, MASS.

FIGURE 7



WATER RESOURCES DEVELOPMENT PROJECT
MERRIMACK RIVER BASIN

RIVER PROFILES
MERRIMACK RIVER AND
PRINCIPAL TRIBUTARIES

NEW ENGLAND DIVISION, WALTHAM, MASS.

FIGURE 8

The water equivalent of the snowpack usually reaches a maximum of about 5 inches in the month of March with a maximum recorded water equivalent of 11 inches over the past 19 years.

Average annual runoff at Hopkinton Dam is approximately 22 inches, which is equivalent to an average runoff rate of about 1.6 cfs per square mile of drainage area. The average flow at the dam is about 700 cfs. The average annual runoff at Everett Dam is approximately 20 inches or about 50 percent of the annual precipitation, equivalent to an average runoff rate of about 1.5 cfs per square miles of drainage area. The average flow at the dam is about 96 cfs.

The Contoocook and Piscataquog drainage basins are underlain by igneous and metamorphic bedrock which was later sculptured by glacial scouring and the erosive action of surface waters. A veneer of relatively recent glacial till and stratified deposits is now to be found in most places overlying topography earlier formed by the structural evolution of the region and by subsequent geomorphological processes. The structural framework of the area conforms with that of the Appalacian regional province in which topographic highs and lows generally trend in a north-northeasterly and south-southwesterly direction. The Contoocook River valley above Henniker generally conforms to the controls imposed by the structure of the bedrock. The glacial and surficial alluvial deposits are thickest in the lower elevations of the region where streams and ponds exist.

No mineral deposits of any significant value, except sand and gravel, have been found in the project area.

The soils of the area are mostly derived from the underlying granites, gneisses and schists, more or less modified by the size-sorting of glacial meltwaters and the more recent sedimentation activities of streams. These soils are generally assigned to the podzolic category of soils, though some areas in the bottom lands have alluvial and humic soils.

Elevations in the close vicinity of the project area vary only moderately, ranging from about 1400 feet NGVD to 340 feet NGVD. The area might be described as gently rolling with rounded hills and rather broad valleys. A topographic map of the project area is shown on Figure 9.

The interspersion of woodland, agricultural land and brush or fallow land reflects both the variations in topography and the changes in land use over periods of time. Woodland comprises nearly 50 percent of the project area and various species of northern hardwoods are mixed with pine and hemlock. A portion of the agricultural land, which made up 10 percent of the project area when construction work first began, is leased as pasture, hay and corn fields to local farmers. The remaining agricultural land, now abandoned, is fast reverting to brushland as it is being invaded by various pioneer species such as aspen and gray birch. Some fields,

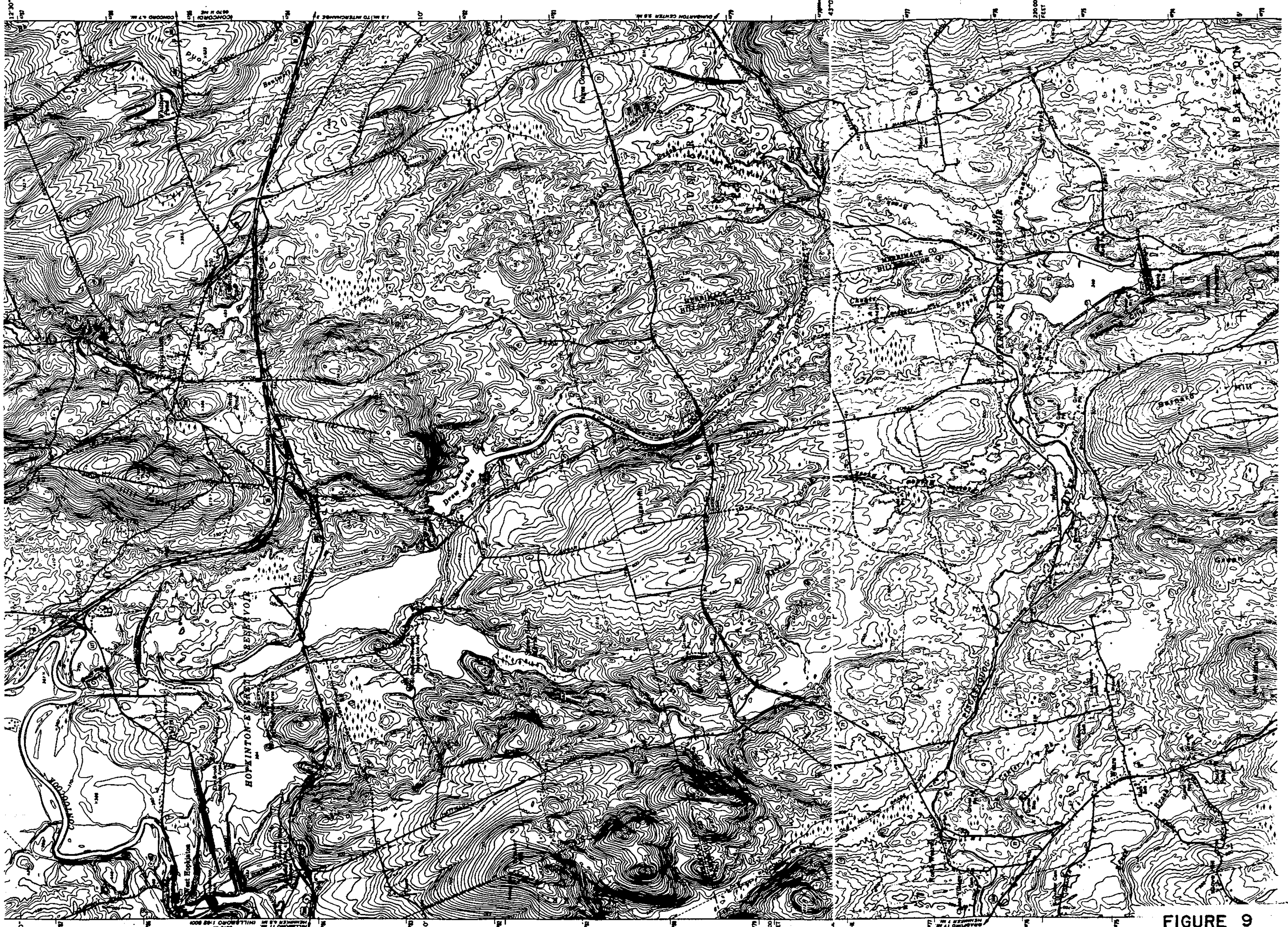


FIGURE 9

however, are kept free of brush, primarily to enhance wildlife habitats. Another 10 percent of the project area was originally inventoried in 1958 as brushland and, depending on the site conditions, is now experiencing a normal sucession of vegetation. The lowest areas of the project may be characterized as marshland, or bottom land. About 18 percent of the project area fits into this category. An additional 8 percent of the project area consists of permanent impoundments.

Environmental Setting

The Contoocook River carries both domestic and industrial wastes and these have an adverse effect on the quality of the water, both upstream and downstream from Hopkinton Dam. However, a variety of warm water species of fish are found in the river. These include: bullhead, white and yellow perch, largemouth and smallmouth bass and pickerel. The permanent pools in the reservoir have these same species, with varying species composition. The Piscataquog, on the other hand, is unpolluted at the project site. Fishing pressure on this river and its tributaries near the project, in constrast to the Contoocook River, is quite heavy and increasing.

Natural production of trout in these colder waters is supplemented by stocking. The segment of the river from Everett Dam to Goffstown has been stocked by the State with as many as 6000 yearling trout annually.

There are numerous beaver flowages on the low-gradient tributaries flowing into the project area. Waterfowl are found seasonally in these same permanently flooded areas. Muskrats, mink, fishers and otters also live close to these waterways.

The upland habitats for a variety of wildlife are fair to excellent and are enhanced by the interspersion of the various types of vegetative cover found in the reservoir site. The project area also supports a good population of white-tailed deer. Grouse, woodcock and pheasants are the principal game birds present. The New Hamsphire Fish and Game Department routinely stocks the area with pheasants. Snowshoe hares, cottontails, gray squirrels, raccoons, foxes, weasels, and skunks also inhabit the reservoir area. Sufficient diversity of both food and habitat has sustained relatively stable populations of these species.

Currently there are no Federally listed threatened or endangered species known to occur in the project area.

Below Hopkinton Dam the Contoocook River meanders in an almost mile-wide flood plain. The vegetative and timber cover seems to have been little affected by changes in water level or flow regimens of the river. The area is both forested and open, the higher ground supporting stands of white pine and the lower elevations and more open areas covered by shrubs, reeds and other grasses. No recent effects of flow regulation or flood releases on vegetative cover were observed during an inspection of the valley downstream from the Hopkinton Dam.

The Piscataquog River valley downstream from Everett Dam is, for more than four miles to Riverdale, rather narrow and wooded. But just upstream from Goffstown and below Riverdale near where the river turns more eastward from its southerly course and at a point near where the combined Middle and South branches join the main branch of the Piscataquog River, the valley becomes broader and more populous.

Vegetation and timber along these two rather different stretches of the Piscataquog has, for many years, successfully adapted to a range of site conditions. Flood flow releases and regulated river stages have had no noticeable effect either on the timber stands (both hardwood and softwood) and the occasional marshland in the narrow upper section of the river valley, or on the open fields with marshy borders and occasional clumps of pine, poplar and red maple in the lower section of the valley.

There have been some tree kills around the margins of the reservoir, and these had a deleterious effect, principally at Elm Brook and Everett pools, where public appreciation of aesthetic values at recreation sites is important. Some tree kills, however, in large portions of the lowest flooded areas, such as Stumpfield-Mudgett Marsh and parts of Elm Brook Pool, were anticipated and intentional because, until they rot and disintegrate, these dead and dying trees enhance waterfowl habitat.

During normal non-flood periods both Hopkinton (Hoague-Sprague) and Everett Dams impound conservation pools. The Hopkinton pool has a surface area of 120 acres at an elevation of 380 feet NGVD, a shoreline length of 55,500 feet and a maximum depth of 15 feet. The Everett pool has a surface area of 130 acres at an elevation of 340 feet NGVD, a shoreline length of 29,800 feet and a maximum depth of 15 feet.

There are no known significant point source discharges to the Piscataquog River upstream from the Everett Lake and the river generally meets the requirements of its Class B rating. However, during high flow conditions requiring reservoir regulation at Hopkinton Lake, water from the Contoocook River is diverted through Drew Lake and Choate Brook to Everett Lake. Although the water quality in the Contoocook River is poorer than that in the Piscataquog River, the effect of diversion on the water quality of the Piscataquog should be small. First because the diversions occur only under high flow conditions when the pollution in the Contoocook would be diluted and the Piscataquog would have greater assimilative capacity, and, second, because the diversions are infrequent events.

Violations of water quality criteria which have been recorded at Everett Lake include frequent low pH; occasional high levels of nutrients, coliforms, and zinc; and rare low DO levels. The low pH levels are probably due to acid rain falling on poorly buffered New Hampshire soils. High nutrients and zinc levels are most likely due to natural conditions, but the data on zinc are not complete. The high coliform counts are due to individual discharges in the watershed. Low DO levels are due to natural conditions.

The existing pool at Everett Lake is about 15 feet deep and experiences weak temperature-induced density stratification during the summer. Dissolved oxygen at the bottom of the pool can be entirely depleted at times; however, the weir discharge and reaeration in the conduit outfall structures keep the downstream DO levels high.

Although there are a number of significant point sources, including industrial and municipal wastewater discharges, upstream from Hopkinton Lake the actual condition of the river as it flows through the project has improved in recent years from Class C to approaching Class B.

Water quality parameters which frequently violated the criteria at Hopkinton Lake include low pH, high nutrients, high color, high coliform counts, and high levels of zinc. There have also been some rare violations of minimum DO levels. The low pH is probably due to acid rain falling on poorly buffered New Hampshire soils. High nutrients, coliforms and color are due to upstream discharges and overflows, although much of the color may also be due to natural conditions. The source of zinc may be upstream discharges or natural conditions; the data on zinc are incomplete. Low DO levels in the lake are caused by upstream discharges; aeration through the outlet works keep the occurrence of low DO levels in the discharge at a minimum.

Cultural Social and Economic Setting

The towns of Henniker, Hopkinton, Weare and Dunbarton collectively had a 1980 population slightly in excess of eleven thousand persons.

The population of the towns in which the project is located and the major cities within 30 miles of the project are shown in Table 2.

TABLE 2
Population Data - 1980

Hopkinton	3,861	Manchester	90,936
Henniker	3,246	Nashua	67,865
Weare	3,232	Concord	30,400
Dunbarton	1,174		

Many of these people are employed in Concord, Manchester and even Nashua, but a substantial number of them work in small outlying plants, industries and offices which are, like the four project-area towns, satellites of the three large urban complexes to the east and south. Many other residents of the four towns are employed in small scale agricultural enterprises, recreational services and private educational institutions; some are retired persons, of whom a sizable number have recently immigrated to the area from outside of New Hampshire. Though New Hampshire experienced a population increase of over 24 percent from 1970 to 1980 the four towns in which the project is located grew at greater rates, ranging from 28 percent to 75 percent, during the same period. Concord and

Manchester, in contrast to this trend, had population changes of +4 percent and +1 percent during the same period.

About 822 acres of agricultural land owned in fee by the Corps is leased to local residents for pasture and hay-growing. This leased acreage, in numerous parcels, is mostly along the Contoocook River valley between Henniker and West Hopkinton. Occasional flooding of these areas by flood storage operations does not usually have serious impact on the local agricultural economy, but the 1973 summer flood did cause substantial damage to pasture and croplands, hurting marginal farmers who had no way to recoup their losses.

Hopkinton-Everett Lakes provides a valuable resource for a variety of outdoor recreation activities. The 8,000 plus acres of Federally owned land within the reservoir area, including 650 acres of permanent water, are available for use by the general public except during the infrequent periods when floodwaters are impounded. The permanent water areas, streams and rivers within the project offer opportunities for fishing, boating and swimming in the summer, while snowmobiling and ice fishing on the frozen, snow covered lakes are very popular recreation activities in the winter. The land area is available for picnicking, hiking, ski touring, snowmobiling, nature study, horseback riding and other leisure time activities.

Four areas within the project boundaries provide opportunities for waterbased recreational activities: Contoocook River Pool, Elm Brook Pool, Drew Lake and Everett Lake. Stark Pond is intentionally preserved as a quiet picnic site and has no provision for swimming.

The Contoocook River Pool, upstream from the Hopkinton Dam, is accessible from the River Road boat launching area 1-1/2 miles west of the dam. However, this attractive area, because it is west of the main part of the project and on the south side of the river, is not heavily used by the public.

The Elm Brook Pool Recreation Area is the most intensively used of all of the Corps-managed facilities. Swimming and picnicking (40 tables and fireplaces) facilities are provided along with a change house, toilet facilities and a ball field. A sand beach for swimming has been constructed at the permanent pool, however, the water depths are shallow and the bottom conditions are muddy. Future plans call for improvement of the beach and parking area.

Drew Lake is primarily used for informal picnicking and fishing. Management and maintenance of this area does not present any significant problems.

Recreation facilities at Everett Lake are managed by the State of New Hampshire under a lease agreement. A single access road to these facilities at Clough State Park is located just northeast of Everett Dam. Like Elm Brook Pool this is an intensively used area.

Clough State Park predated the construction of Everett Dam. Some dislocation of facilities in the Park was necessitated by the dam, but the permanent pool and shoreline recreation area complement the older facilities of Clough State Park. The addition of Everett Lake, has stimulated increased recreational use of the park and the neighboring areas.

About 200 picnic tables and parking for 250 cars are provided, as are two change house-restrooms, drinking water, a field sports area and a boat ramp with parking for about 40 cars and trailers. Periodic flooding increases maintenance requirements for facilities within Clough State Park.

Both the State and the Corps maintain a number of roads throughout the project year-round for use by fishermen, hunters, snowmobilers and other visitors. Snowmobiling is an especially popular winter activity. The Corps, in cooperation with the New Hampshire Bureau of Off-Road Vehicles, has pursued a trail designation program throughout the project, whereby unplowed roads and trails are mapped and marked for snowmobile use.

There are only two known historic/cultural sites in the project area. One is the historic homestead of General Stark of Revolutionary War fame, located above the Everett spillway elevation at the intersection of Stark Lane and Mansion Road in Dunbarton, not far from Stark Pond. The old Stark family cemetery has been relocated about a half mile south of Stark Mansion on Mansion Road.

The other, known as the Dinner Pine, a 150 year old bull pine tree about 14 feet 9 inches in circumference and 4 feet and 8 inches in diameter, located in Henniker's southeast valley about 1/2 mile from the Old Ireland Road will be preserved and protected as an historic landmark. In the 19th century this tree provided the only shade for men working in the surrounding fields. Farmers would leave their lunch pails under the Dinner Pine and return at noon to eat their lunches. The tree is represented in the Henniker town mural painted for the Bicentennial.

Reservoir Regulation

The principal objective of the Hopkinton-Everett Lakes Project is FLOOD CONTROL: the protection of downstream communities on the Contoocook and Piscataquog Rivers and, in conjunction with several other Corps projects, for communities along the Merrimack River.

Contoocook River floodwaters are impounded behind Hopkinton Dam above the normal level (elevation 380 feet NGVD) and upon reaching the invert of Canal No. 1 (elevation 384 feet NGVD) flow into Elm Brook Pool. Upon filling Elm Brook Pool to elevation 400.5 feet, NGVD the floodwaters spill over the uncontrolled North Weir at Drew Lake and then spill over the uncontrolled South Weir of Canal No. 2 (elevation 399.35 feet, NGVD) into Choate Brook and Everett Lake (normal elevation 340.0 feet NGVD). Floodwaters are evacuated by operating the outlet gates at Hopkinton and Everett Dams and releases are coordinated with those from other reservoirs in the Merrimack River system. The release rates from the reservoir are dependent upon river conditions at the downstream damage centers.

Following the downstream recession of the flood on the Merrimack River, stored floodwaters are released as rapidly as possible, consistent with amounts of reservoir storage utilized, downstream flows, channel capacities, weather forecasts and travel times. The maximum non-damaging channel capacity in the Contoocook River downstream from Hopkinton Dam is 7,000 cfs. The maximum non-damaging release rate at Everett Dam is 1,500 cfs. Releases of these magnitudes are not usually made unless considerable flood control storage has been utilized. The Corps has obtained flowage easements on all downstream lands which are effected by such releases.

During the release phase, the levels at downstream points should not exceed flood stage; however, during an unusual flood it is possible that flood stages may continue to be exceeded due to runoff from uncontrolled downstream tributaries, and it may be necessary to begin releases once the stage has crested.

Ordinarily during a major flood, the gates would not be opened to avoid spillway discharge. Surcharge storage above the spillway crest would be utilized if downstream channel capacities continue to be exceeded by runoff from uncontrolled areas. However, if the stage in the reservoir continued to rise above the crest with the possibility of endangering the structural integrity of the dam, releases might be made through the gates. Under such circumstances state and local police would be advised of the threat.

It is conceivable that an extraordinary situation may arise, such as: drowning, dam or bridge failure, highway or railroad washout, ice jam or debris deposit. Since the purpose of the reservoir is to save lives and prevent or reduce damage, regulation during such unusual conditions may not follow previously described rules, but will be governed by the urgency of the circumstances. During such situations the gates are closed immediately to contain waters behind the dam.

It is the policy of the Corps of Engineers to cooperate with downstream water users and other interested parties or agencies. The Project Manager may be requested by downstream users to deviate from normal regulation for short periods. Whenever such a request is received, the manager shall ascertain the validity of the request and obtain assurances from other downstream water users that they are agreeable to the proposed operation.

Future Conditions Without the Project

No significant changes in the physical, environmental, cultural, recreational, social and economic conditions are anticipated in the study area. No significant changes in reservoir regulations are envisioned. However, the projected gradual growth could result in subtle changes in the environment and water quality.

Problems, Needs and Opportunities

New England depends heavily on oil for its electricity. About 60 percent of the region's electricity is produced at oil-fired generating stations. Given the instability of oil supplies and the fluctuating prices associated with them, the need for the development of renewable resource projects is apparent. The addition of hydropower at Hopkinton-Everett Lakes would reduce the region's dependence on oil for the production of electricity.

Planning Constraints

General planning constraints and guidance for this investigation are contained in Public Law 91-190, National Environmental Policy Act; Public Law 91-611, River and Harbor and Flood Control Act of 1970; Public Law 92-500, Federal Water Pollution Control Act Amendments of 1972; Public Law 93-251, Water Resources Development Act of 1974; and the Water Resources Council's, "Principles and Standards for Planning Water and Related Land Resources."

In the design of any hydropower addition, measures must be taken, to the extent possible, to minimize environmental and social disruptions. Since there are no known endangered species in the project area, consultation under Section 7 of the Endangered Species Act of 1973 will not be required.

A funding constraint severely limited the scope of studies associated with this reconnaissance report. Environmental, socioeconomic and recreational data contained in this report were taken directly from past reports. No attempts were made to verify or update that data. Possible potential impacts have not been identified. Assumptions made regarding the infringement on existing flood control storage and impacts on reservoir regulation activities, as well as on the design and cost estimates, reflect this limitation. If this investigation continues, future studies will include detailed hydrologic and reservoir regulation studies to determine whether the proposed infringement on flood control storage or any loss of storage will have a significant adverse impact on flood control protection within the Merrimack River Basin. For this report, it was assumed that the Corps would plan, develop, construct and operate the hydropower addition.

Problem and Opportunity Statements

Hydropower additions being considered would provide an opportunity over the next 50 years to:

- Increase New England's energy supply and the nation's energy independence.
- Develop and utilize a native renewable energy resource to its maximum potential.

III. FORMULATION OF PLANS

Plan Formulation Rationale

The purpose of this investigation is to determine the feasibility of adding hydropower facilities at Hopkinton-Everett Lakes. Due to the limited scope of this report, it was decided that only run-of-river alternatives would be considered.

EHC Hydro Associates of Boston, Massachusetts owns the water rights at Hopkinton Dam to elevation 380 feet NGVD, which is the top of the permanent pool maintained at that site. EHC Hydro is currently constructing a hydroelectric generating facility downstream of Hopkinton Dam and intends to utilize the water stored at elevation 380 feet and below. It is possible to raise the permanent pool at Hopkinton to develop an additional hydroelectric generating facility but an adverse impact on the water quality of Elm Brook pool could occur.

As previously mentioned the Contoocook River carries both domestic and industiral wastes which have an adverse effect on the quality of water. By raising the permanent pool, water from the Contoocook will be diverted into the Elm Brook pool via Canal No. 1. Although these diversions occur during periods of reservoir regulation, they have minimal effect on water quality because the diversions are not frequent and only occur under high flow conditions when the pollution in the Contoocook would be diluted. Because it is believed that permanent diversions could have a detrimental effect on the water quality of the Elm Brook pool, no alternatives were developed for evaluation at the Hopkinton site.

At Everett Lake several alternaties were formulated, however, due to funding constraints, only two were developed to the point where a full preliminary assessment of their economic feasibility could be made. The drainage area above Everett Dam is 64 square miles and the average flow is 96 cfs.

The first alternative evaluated requires that the permanent pool be raised from elevation 340 feet NGVD to elevation 370 feet resulting in a net power head of 42 feet. A downstream powerhouse was selected for this alternative.

The second alternative evaluated would utilize the existing 15 foot deep permanent pool at Everett Dam and locate small submersible turbine-generator units in the existing control weir located upstream of the flood control gates. No powerhouse would be required since the control panels for this plant could be located in the intake tower.

Plans of Others

Currently no other entity is known to be studying Hopkinton-Everett Lakes for hydropower development.

Description of Plans

Alternative 1 consists of a 750 mm standard tube unit located just downstream of the existing outlet structure, as shown in Figure 10. The existing permanent pool would be raised from elevation 340 feet NGVD to elevation 370 feet and maintained using an additional set of gates which would be located downstream near the powerhouse. Under the 42-foot net head, the unit would be rated at 350 kW and produce about 1,310,000 kWh annually. Creating the deeper permanent pool would utilize all available flood control storage encroachment at the Hopkinton-Everett Lakes Project. This alternative would operate as a run of river project with daily pool fluctuations of less than one foot. Raising the pool to 370 feet NGVD results in several impacts, most notably the inundation of the Clough State Park recreation area.

Alternative 2 consists of two mini-submersible turbine-generator units that would be installed in the existing 15 foot weir located upstream of the flood control outlet as shown in Figure 11. Each unit has an inductive generator with a capacity of 94 kW, therefore this alternative would have a total capacity of 188 kW. Generation would occur whenever flows range from 46 cfs to 224 cfs thereby giving excellent operational flexibility. Since the entire unit is submerisble there is no need for the construction of a separate powerhouse. The controls of the unit can be installed in the flood control tower directly above the weir. Since the reservoir is currently regulated by the weir and this alternative would not raise the permanent pool, operations for hydropower generation are quite similar to present operations. This alternative would have a net hydraulic head of 14 feet and is capable of generating 435,600 kWh of energy annually. The project would operate as a run of river project with daily pool fluctuations of less than one-foot.

Power Estimates

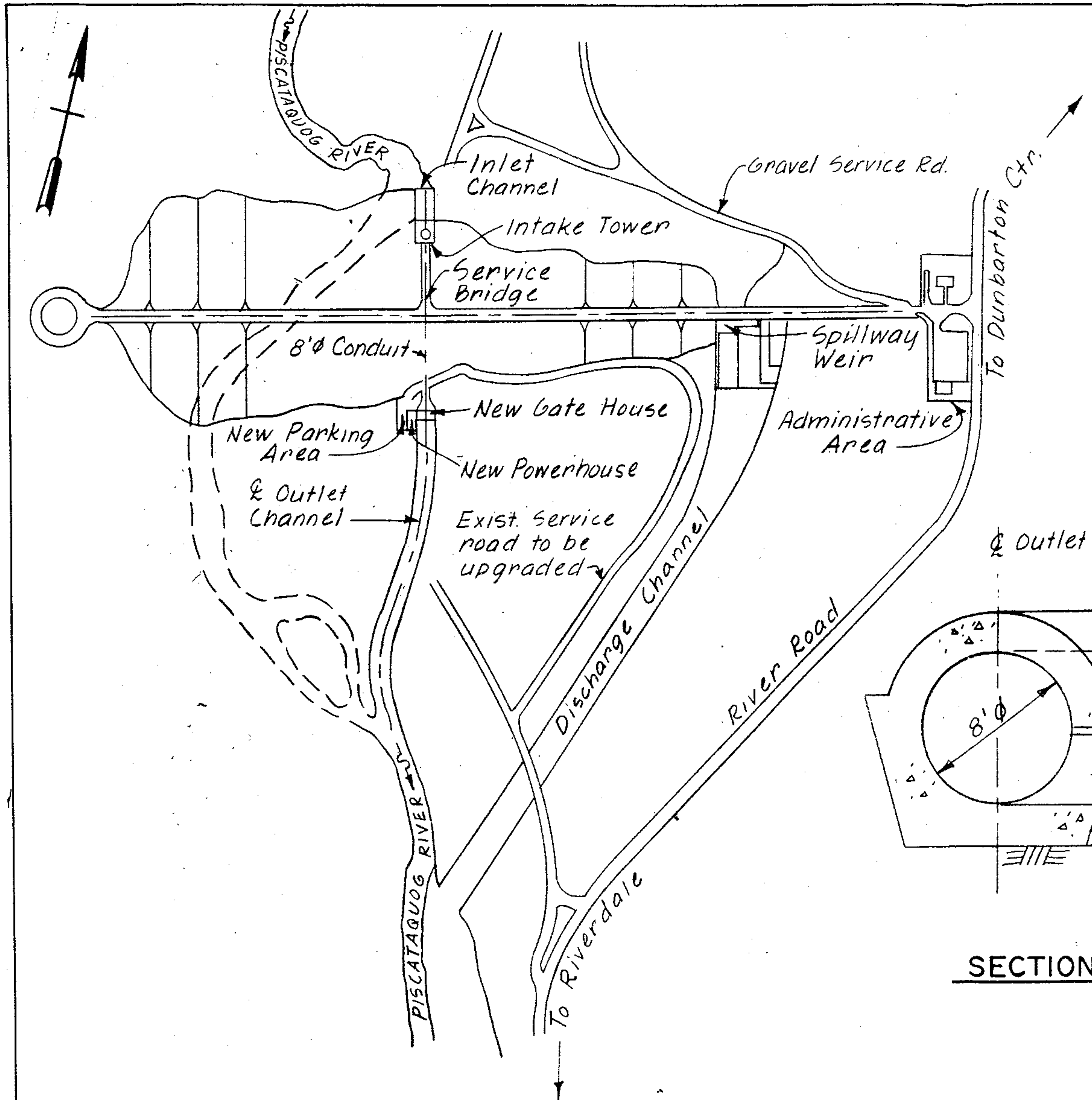
The hydropower potential of a volume of water is the product of its weight and the vertical distance it can be lowered. Water power is the physical effect of the weight of falling water. The function of a water-power facility is to transform this gravitational potential energy into mechanical energy, by turning a turbine, for utilization in creating electrical energy via a generator. The potential rate of power generation, normally measured in kilowatts, is determined by the formula:

$$P = \frac{EHQ}{11.8}$$

where:

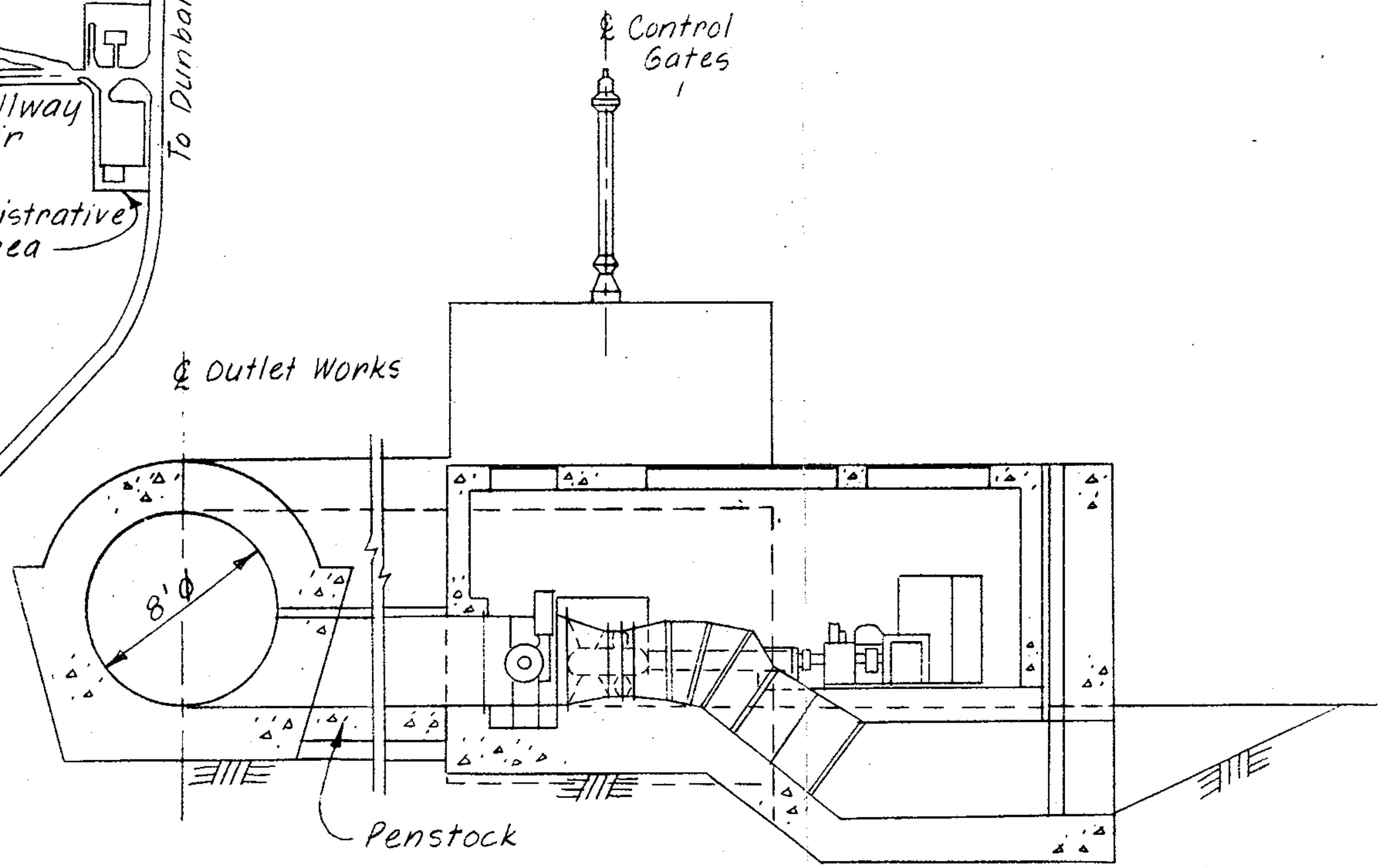
P = Power or capacity in kilowatts
E = Combined turbine and generator efficiencies
Q = Rate of discharge in cubic feet per second
H = Net hydraulic head in feet.

TYPE OF TURBINE	HORIZONTAL TUBE UNIT
CAPACITY	350 KW
NO. OF UNITS	1
NET HEAD	42 FT.
DESIGN "Q"	125 CFS
RUNNER DIA.	750 MM (29.5")



PLAN

N.T.S.



SECTION THRU CONDUIT AND ALONG ℄ TURBINE

N. T. S.

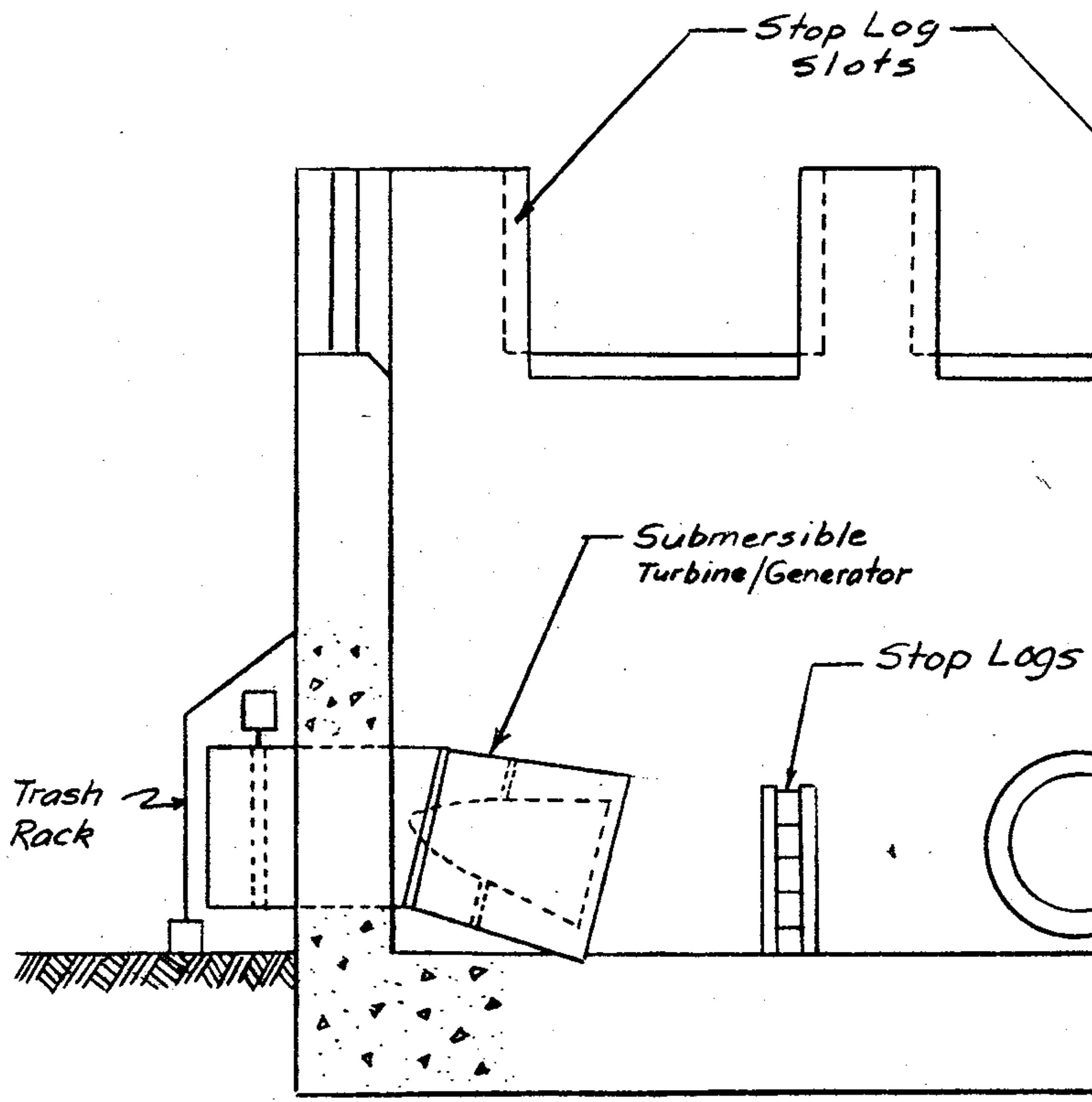
RECONNAISSANCE REPORT
HOPKINTON-EVERETT LAKES
HYDROPOWER STUDY

ALTERNATIVE I
EVERETT LAKE

PLAN & SECTION

PISCATAQUOG R., NEW HAMPSHIRE

FIGURE 10



SECTION A-A
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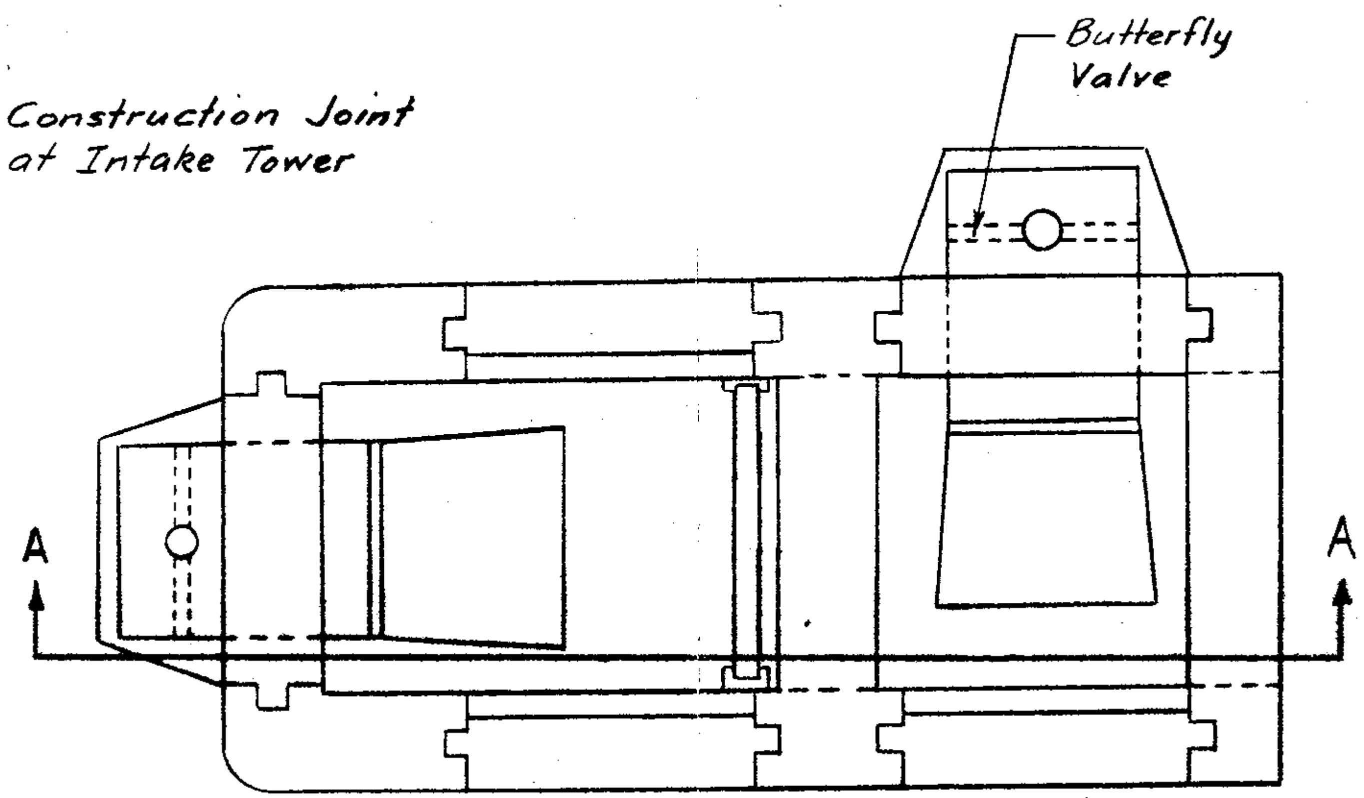

PLAN OF WEIR
not to scale

RECONNAISSANCE REPORT
HOPKINTON - EVERETT LAKES
HYDROPOWER STUDY
ALTERNATIVE 2
EVERETT LAKE
PLAN & SECTION

FIGURE 11

With today's highly efficient turbines and generators, an average combined efficiency of 80 percent for the standard tube unit and 60 percent for the submersible can be reasonably assumed for a typical range of operating head and discharge conditions. The potential amount of power generation over a period of time, "energy," is normally measured in kilowatt-hours and is equal to the average capacity times the duration of generation.

The potential amount of waterpower of any stream, river or lake is a function of: (1) the average annual streamflow and (2) the average annual hydraulic head. Both the rate of discharge and the head are quantities which may fluctuate; therefore, it is the magnitude of these two quantities and their variability that determine the potential energy of a site and its dependability.

The average annual runoff at Everett Dam is approximately 20 inches or about 50 percent of the annual precipitation, equivalent to an average runoff rate of about 1.5 cfs per square mile of drainage area.

A U.S. Geologic Survey gaging station (gage #01090800) is located on the Piscataquog River below Everett Dam, near East Weare, New Hampshire (500 feet downstream from Everett Dam). The gage has recorded river discharges since 1965. Table 3 lists average monthly recorded flows over the past 17 years. Because Everett Dam as well as Hopkinton Dam are operated principally for short-term flood control, the monthly flows recorded at the downstream gaging station are considered representative of the natural monthly streamflows at Everett Dam. The average annual flow at the dam was calculated to be about 96 cfs.

TABLE 3

Average Monthly Flows (1965 to 1981)
Piscataquog River at Everett Dam, East Weare, New Hampshire
(D.A. = 64 sq. mi.)

Month	Average Flow Cfs	Average Flow Inches	Percent Annual Runoff
January	77	1.39	6.8
February	88	1.43	7.0
March	199	3.58	17.6
April	290	5.05	24.8
May	152	2.74	13.4
June	53	0.92	4.5
July	28	0.50	2.5
August	15	0.27	1.3
September	18	0.31	1.5
October	64	1.15	5.6
November	80	1.39	6.8
December	92	1.66	8.1
Annual	96	20.39	

The hydropower potential at Everett Dam for Alternative 1 was estimated by assuming a total flood control storage encroachment, on the combined Hopkinton-Everett reservoir system, of 9,515 acre-feet, which is equivalent to about 0.4 inches of runoff from the net drainage area of 446 square miles. An encroachment of 0.4 inches or 9,515 acre-feet, on the total combined available flood control storage of 161,600 acre-feet, was considered the maximum encroachment for use in assessing hydropower feasibility. The hydropower potential at Everett Dam for Alternative 1 was investigated allowing for the total 9,515 acre-feet of storage encroachment at Everett Dam while maintaining Hopkinton Dam at its existing condition. A total of 9,515 acre-feet of storage encroachment results in a new permanent pool at Everett Dam of 370 NGVD.

Further analysis of the effects of encroachment for hydropower would have to be a part of any more detailed studies. The feasibility of raising or modifying the dam for added storage was not investigated as part of this study.

The Piscataquog River, just downstream from Everett Dam, is relatively flat, therefore, the use of penstocks to gain additional head would not be feasible. It was assumed that a powerhouse would be located at the downstream toe of the dam for Alternative 1. Average tailwater elevation was computed to be 326 feet NGVD and hydraulic losses were assumed about 2.0 feet, resulting in a total net power head of 42 feet assuming a permanent pool elevation of 370 feet NGVD, (pool elevation-tailwater elevation-hydraulic losses).

For Alternative 2 the hydropower potential was determined at Everett Dam utilizing the existing permanent pool of elevation 340 feet NGVD. Although by maintaining the existing pool the average annual generation potential is less than in Alternative 1, Alternative 2 operates essentially the same as present operations, will not alter existing conditions and will not impact on Clough State Park.

The existing 15-foot box weir located upstream of the middle flood control gate would be modified to include the submerisble turbine-generator units. No modifications to the flood control gates or oulet works would be necessary. This plan would result in a net power head of 14 feet.

Alternative 1 assumed an average turbine-generator efficiency "E" of 80 percent and Alternative 2 assumed an average efficiency of 60 percent.

Since the flow duration curve is a measure of the magnitude and variability of flow, the area under the curve, within the operating limits of the facility, assumed to be 105 and 40 percent design capacity, is proportional to the average annual energy potential of the site.

Flow duration analyses were performed for single-unit configurations as well as for multiple unit configurations. The relationship between average annual energy and installed capacity for single and multiple-unit configurations was derived. The flow duration curve for the Hopkinton and Everett alternatives is shown in Figure 12.

Cost Estimates

Cost estimates were prepared using the Corps' publication entitled "Feasibility Studies for Small Scale Hydropower Additions," supplemented by site-specific estimates based on standard engineering practice. First cost estimate for Alternative 1 is presented in Table 4 and the first cost estimate for Alternative 2 is presented in Table 5. Annual costs for both Alternatives are shown in Table 6.

TABLE 4

First Costs for Alternative 1

Item	Cost
Grading, Drainage and Erosion Controls	10,000
Access Roads	25,000
Parking & Misc. Site Features	43,000
Environmental Controls During Construction	14,000
Tunnel Lining	140,000
Penstock	28,000
Gate Structure	590,000
Turbine and Generator	770,000
Powerhouse	160,000
Station Electrical Equipment	100,000
Misc. Mechanical Equipment	55,000
Transmission Line	15,000
Control of Water	60,000
Subtotal	2,010,000
Contingencies	390,000
First Cost	2,400,000

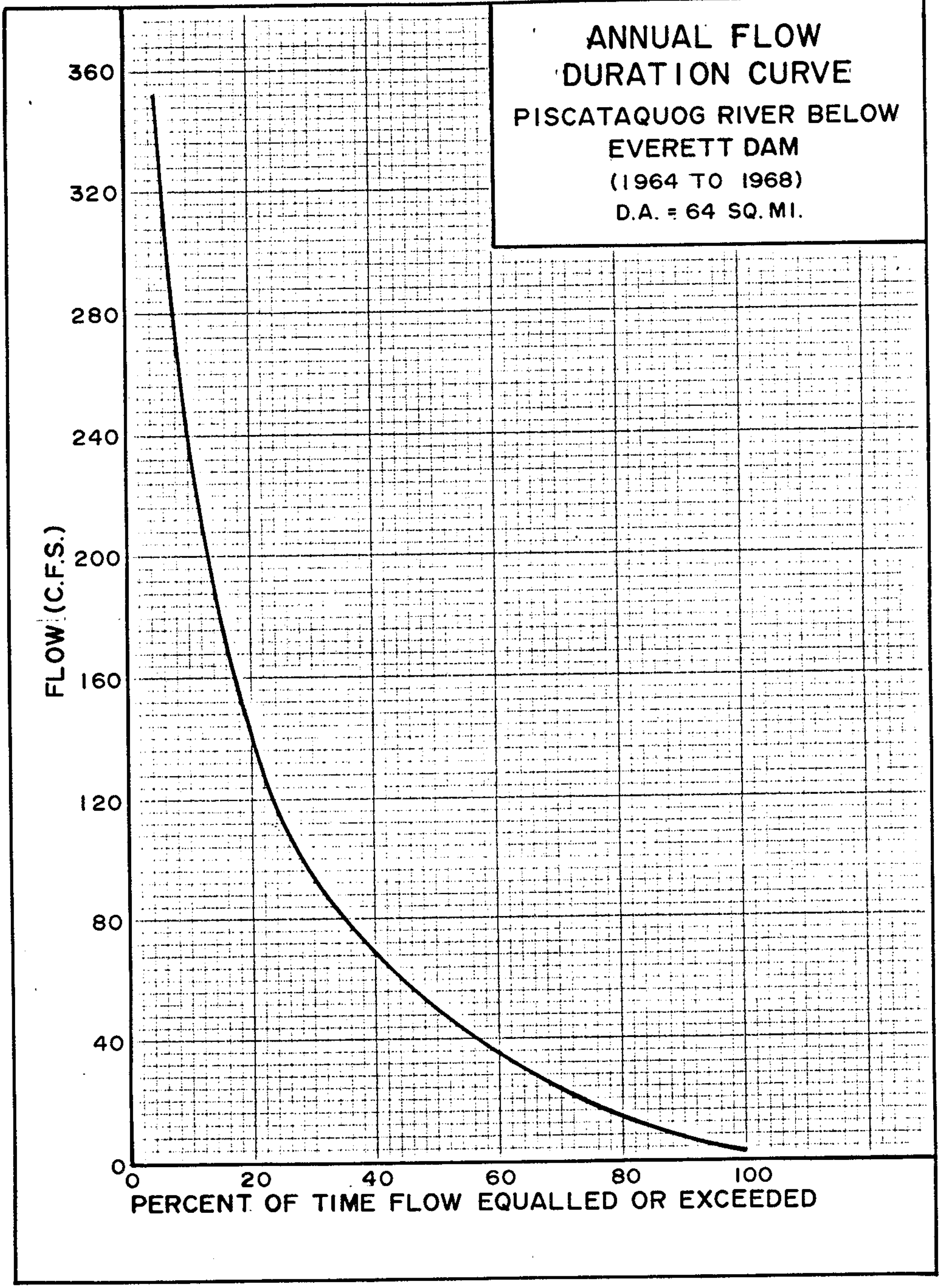
ANNUAL FLOW
DURATION CURVE
PISCATAQUOG RIVER BELOW
EVERETT DAM
(1964 TO 1968)
D.A. = 64 SQ. MI.
FLOW (C.F.S.)
360
320
280
240
200
160
120
80
40
0
0
20
40
60
80
100
PERCENT OF TIME FLOW EQUALLED OR EXCEEDED

FIGURE 12

TABLE 5

First Costs for Alternative 2

Item	Cost
Environmental Controls During Construction	5,000
Turbine-Generators	120,000
Switchyard Equipment	40,000
Transmission LIne	15,000
Weir Modifications	20,000
Intake Trash Racks	2,000
Control of Water	20,000
Subtotal	222,000
Contingencies	33,000
First Cost	255,000

TABLE 6

Annual Costs for the Alternatives

	Alternative 1	Alternative 2
First Costs	$2,400,000	$ 255,000
E&D and S&A (17%)	408,000	45,000
Total Investment	2,808,000	300,000
I&A (0.08057)	226,000	24,200
OM&R*	35,000	15,000
Annual Cost	$261,000	$ 39,200
Energy Cost	199 mills/kwh	90 mills/kwh

*The submersible turbine-generators of Alternative 2 require very little maintenance. Manufacturers of this equipment claim the units have a service life of 30 years. For the purpose of this evaluation it was assumed the units service life to be 15-20 years and the OM&R costs were increased over the anticipated operation and maintenance needs to act as a sinking fund replacement cost.

Economic Evaluation

Power values used for this evaluation were provided by the Federal Energy Regulatory Commission (FERC). They are based on the displaced energy costs analysis methodology described in the Water Resource Council's recent report entitled "Implementing Procedures for Evaluating Hydropower Benefits." A letter from FERC, transmitting power values and discussing their derivation is shown in the correspondence appendix. Based on those power values, the following annual benefits were derived.

Alternative 1	=	42 feet of head
Installed Capacity	=	350 kW
Average Annual Energy	=	1,310,000 kWh
Plant Factor	=	43%
Average Annual Benefits	=	1,310,000 (.100) = $131,000
(assuming no transmission losses)		

Alternative 2	=	14 feet of head
Installed Capacity	=	188 kW
Average Annual Energy	=	435,600 kWh
Plant Factor	=	26%
Average Annual Benefits	=	435,600 (.112) = $48,800

Based on the annual costs presented earlier, the following benefit to cost ratios were calculated:

Alternative 1: $\frac{131,000}{261,000} = 0.50$

Alternative 2: $\frac{48,000}{39,200} = 1.24$

Reservoir Regulation

If hydropower facilities were eventually built at Hopkinton-Everett, the primary purpose of the project would remain flood control, and all flood control activities would override the requirements of hydropower generation. This control would be retained by the Division Engineer through the Corps' Reservoir Control Center.

IV. CONCLUSION

The purpose of this investigation was to determine the potential of adding hydroelectric generating facilities to the existing Corps flood control project at Hopkinton-Everett Lakes. Since the water rights up to the existing permanent pool at Hopkinton Dam are owned by others and a permanent raising of the pool could have a detrimental water quality impact on Elm Brook pond, no alternatives for hydropower development were formulated at Hopkinton.

Two alternatives for hydropower development at Everett Lake were considered. The first alternative calls for raising the permanent pool 30 feet and adding a 350 kW unit at the downstream end of the existing flood control outlet works. This alternative is capable of generating 1,310,000 kWh annually at a cost of 199 mills per kWh. The benefit cost ratio for this alternative is 0.5 to 1.

The second alternative would locate two 94 kW submersible turbine-generator units in the 15-foot recreational weir located upstream of the flood control outlet. No increase in the permanent pool is required for this alternative. This alternative is capable of generating 435,600 kWh annually at a cost of 90 mills per kWh. The benefit-cost ratio for this alternative was 1.24 to 1. Since alternative 2 has a benfit cost ratio that exceeds unit it is considered economically justified and warrants further investigation.

V. RECOMMENDATION

The concept of installing submersible turbine generator units in the recreational weir upstream of the dam resulted in an alternative with a benefit cost ratio exceeding unity. The use of submersible units is relatively new technology and hydropower generation. Although the units cannot produce the average annual energy that a downstream powerhouse utilizing a higher permanent pool is capable of generating, they allow great operational flexibility and allow the hydropower facility to be added without significantly alterating existing conditions or operations. Because the submersible units will operate under existing available head there is no need to raise reservoir pools and therefore the impacts of such raising are avoided.

Our investigations to date indicate that through use of submersible generating equipment the addition of hydroelectric generating facilities at Everett Lake is both technically feasible and economically justified. It is therefore recommended that the Everett Lake Hydropower Project proceed to the Feasibility Study stage where an array of technically feasible alternatives using submersible generating equipment can be developed.

ACKNOWLEGEMENTS

This study was conducted by the New England Division, Army Corps of Engineers, under the general supervision of Mr. Joseph L. Ignazio, Chief, Planning Division and Mr. William F. McCarthy, Chief, Basin Management Branch. Investigations were performed by an interdisciplinary project team. Persons primarily responsible for the contents of this report are: Robert LeBlanc and Michael Keegan project managers; Mary Donovan, designs and cost estimates; Paul Marinelli, hydrology and power estimates; Townsend Barker, water quality; and, Camille Santi and Laraine Bogosian, report preparation.

Preparation and distribution of this report would not have been possible without the cooperation of the Division's technical, clerical and administrative staffs. Special thanks is extended to the entire Reprographics Branch staff.

CORRESPONDENCE

APPENDIX

FEDERAL ENERGY REGULATORY COMMISSION
NEW YORK REGIONAL OFFICE
26 FEDERAL PLAZA, ROOM 2207
NEW YORK, NEW YORK 10278

August 9, 1982

Colonel C. E. Edgar III
Division Engineer
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254

Dear Colonel Edgar:

In response to your letter of March 12, 1982, and in accordance with subsequent discussions with members of your staff, we have determined at-market power values for the proposed inclusion of hydroelectric power at four of your existing flood control projects. The values were calculated by three different methods for annual plant factors of 19 through 69 percent in 10 percent increments for a federal interest rate of 7-5/8 percent. Capacity and energy values were computed as of January 1982 based on current construction and fuel prices (snapshot), and energy values were derived using life cycle cost (LCC) and displaced energy cost (DEC) techniques. The snapshot capacity values may also be used in conjunction with the LCC energy values to yield total LCC power benefits. LCC and DEC energy values are based on Department of Energy (DOE) projections released in November, 1981 and reflect levelized fuel costs for the 100-year period following the expected project on line date of 1988.

The power market was taken to be the New England Power Pool (NEPOOL). A baseload, coal-fired, steam plant was used to evaluate proposed installations with plant factors of 49, 59, and 69 percent, and a cycling coal-fired steam plant for 19, 29, and 39 percent plant factors. The capital costs, with federal financing, of generating plants installed on the NEPOOL system are $1,320/kW for a base load, coal-fired plant consisting of a single 600 MW unit and $920/kW for a single intermediate load 400 MW cycling coal unit. Heat rates are taken at 9,500 Btu/kWh for the base load coal plant and 11,000 Btu/kWh for cycling coal. A February, 1982 survey of the coal using utilities in NEPOOL showed the average cost of coal to be $2.30/million Btu's. The at-market values reflect the estimated cost of assumed 345 kV transmission required for delivery of output from the base load and cycling coal alternatives to market.

Snapshot power values consisting of two components, represent a summation of all the annualized costs of contructing and operating a power plant and required transmission for the year following an assumed on-line date during October 1982. The capacity component reflects the fixed costs associated with the construction and operation of the project alternative, with interest expense accounting for the largest portion. The energy, or variable component consists mainly of the cost of fuel consumed. In the case of the LCC values, the snapshot energy values are used as a starting point but are escalated to reflect the increased fuel costs for the 100-year period following the projected project on-line date of 1988. All energy costs were discounted to 1988 to obtain their present worth and then summed. A capital recovery factor was then applied to yield the levelized LCC energy value. The process for calculating the DEC energy value is essentially similar, but in this case it is the cost of the energy displaced in the project market area for each of the 100 years following 1988 which is escalated. The methodology for the displaced energy costs analysis is based on the recently issued Water Resources Council task force report entitled "Implementing Procedures for Evaluating Hydropower Benefits." The annual load duration curves for New England were synthesized from data supplied by NEPLAN for 1981 and future load projections from the Northeast Power Coordinating Council (NPCC) reliability report, submitted to DOE, and the NEPLAN "Red Book." The type of generation displaced was taken from capacity band stackings loaded economically on the annual load duration curve. The projections of capacity changes were also taken from the NPCC reliability report and the NEPLAN "Red Book." These provide information through the year 2002. After 2002 and through 2088, it was assumed that there would be no further change in the types of generation displaced.

Estimated at-market power values are shown on the attached table. The capacity values, rounded to the nearest dollar, are applicable to the project's dependable capacity and the energy values, rounded to the nearest mill, are applicable to the average annual generation.

If we can be of further assistance in your study, do not hesitate to contact us.

Sincerely,

James D. Hebson

James D. Hebson
Regional Engineer

Attachment
As Noted

New England Division - COE

"FOUR CORPS: PROJECTS AT-MARKET POWER VALUES

Annual Plant Factor	%	19	29	39	49	59	69
Alternative	Type	CCP	CCP	CCP	BCP	BCP	BCP
Power Values							
Jan.'82 Price Level							
Capacity	$/kW/Yr	127	127	127	182	182	182
Energy	Mills/kWh	18	26	30	24	25	27
Life Cycle Cost							
Energy	Mills/kWh	25	37	42	33	36	38
Displaced Energy Cost							
Energy	Mills/kWh	112	112	112	100	95	48

Notes: CCP - Cycling Coal Plant
BCP - Base Coal Plant

HYDROPOWER STUDY

EVERETT LAKE, NEW HAMPSHIRE

Attachment to the Reconnaissance Report
Schedule of Work and Budgetary Data

APRIL 1983

Reference ER 11-2-101, Which States That:

BUDGETARY INFORMATION IS NOT TO BE RELEASED
OUTSIDE THE DEPARTMENT OF THE ARMY

SCHEDULE OF WORK AND BUDGETARY DATA

General

During the reconnaissance investigation, a rather new concept was formulated and evaluated for the development of hydropower facilities at Everett Lake. The concept of utilizing small submersible turbine-generator units was determined to be technically feasible and economically justified. A recommendation has been made to initiate a feasibility investigation to evaluate this concept in greater detail.

There is some significant analysis that will be required to evaluate the stability of the submersible units while the project is storing and discharging flood flows. Therefore, at this time only those funds needed to perform this stability analysis and to develop an array of technically and economically feasible alternatives using the submersible units is being requested. It is anticipated that we will require $100,000 and 12 months to perform this preliminary feasibility analysis. If the preliminary feasibility analysis indicates that an implementable plan for Federal participation would not be forthcoming, then a negative report would be prepared. If the preliminary feasibility analysis indicates that more than one plan is feasible then additional study would be performed to select an alternative and evaluate it for presentation as a recommended project for Federal authorization. This final evaluation is estimated to require $60,000 and twelve months to perform. Estimates of cost for each major element of the feasibility analysis are shown in Exhibit 1.

Appropriation History and Proposed Allocations

To date, $10,000 has been expended on the reconnaissance investigation of adding hydroelectric generation facilities to the Everett Lake flood control project. The total current estimated cost of the feasibility study is $160,000. A detailed study is currently scheduled for completion in FY 86. Detailed funding by fiscal year is as follows:

Appropriation History

FY 82	$10,000 (O&M Money)
Total to Date	10,000

Proposed Allocations

FY 85	$100,000
FY 86	60,000
Total	$160,000

Preparation of the Feasibility Report

This reconnaissance report presents baseline conditions in the study area and documents the brief analysis conducted to examine the possible types of hydropower development feasible at the Everett site.

The scheduled feasibility study would examine potential operational problems and design considerations that could be encountered in use of low head low flow submersible turbine-generator units. The feasibility study would also examine an array of technically and economically feasible alternatives using the submersible units. The feasibility study results will be documented in a report following the evaluation of the various alternatives.

RCS: DAEN-CWB-12

STUDY COST ESTIMATE (PB-6) ($000) For use of this form, see ER 11-2-220	APPROPRIATION TITLE: General Investigations CATEGORY: Surveys CLASS: Section 216	NAME OF STUDY: Everett Lakes Hydropower Study, New Hampshire SUBCLASS:

LINE NO.	SUBACCOUNT NUMBER	SUBACCOUNT TITLE	CURRENT COST ESTIMATE: RECON-NOISSANCE PHASE 1/	FEDERAL FEASIBILITY PHASE	NON-FEDERAL FEASIBILITY PHASE	TOTAL FEASIBILITY PHASE	PREVIOUS FEDERAL COST ESTIMATE AND DATE APPROVED (15 Jun 81)	REMARKS
	a	b	c	d	e	f	g	h
1	.01	Public Involvement		5		5	12	1/ funded under O & M Program
2	.02	Institutional Studies		-		-	10	
3	.03	Social Studies		3		3	10	
4	.04	Cultural Resource Studies		2		2	10	
5	.05	Environmental Studies		17		17	45	
6	.06	Fish & Wildlife Studies		4		4	8	
7	.07	Economic Studies		5		5	15	
8	.08	Survey & Mapping		2		2	8	
9	.09	Hydrologic & Hydraulic Investigations		15		15	35	
10	.10	Foundation & Material Investigation		5		5	15	
11	.11	Design & Cost Estimates		20		20	40	
12	.12	Real Estate Studies		-		-	7	
13	.13	Study Management		28		28	65	
14	.14	Plan Formulation		11		11	30	

DATE PREPARED	DIVISION	REGION	
10 Jan 82	New England	New England	Page 1 of 2
	DISTRICT	BASIN	

ENG FORM 2204-R, May 82 REPLACES ENG FORM 2204, APR 77 WHICH IS OBSOLETE.

EXHIBIT 1

RCS: DAEN-CWB-12

STUDY COST ESTIMATE (PB-6)
($000)
For use of this form, see ER 11-2-220

APPROPRIATION TITLE: General Investigations

CATEGORY: Surveys

CLASS: Section 216

NAME OF STUDY: Everett Lakes Hydropower Study, New Hampshire

SUBCLASS:

LINE NO.	SUBACCOUNT NUMBER	SUBACCOUNT TITLE	CURRENT COST ESTIMATE: RECONNOISSANCE PHASE	FEDERAL FEASIBILITY PHASE	NON-FEDERAL FEASIBILITY PHASE	TOTAL FEASIBILITY PHASE	PREVIOUS FEDERAL COST ESTIMATE AND DATE APPROVED (15 Jun 82)	REMARKS
	a	b	c	d	e	f	g	h
1	.15	Report Preparation		12		12	30	
2	.20	Water Quality		2		2	15	
3	.21	Power Marketing Studies		2		2	5	
4	.22	Transmission Studies		2		2	5	
5	.31	S & A		25		25	65	
6								
7		TOTAL		160		160	430	
8								
9								
10								
11								
12								
13								
14								

DATE PREPARED: 10 Jan 83

DIVISION: New England

DISTRICT:

REGION: New England

BASIN:

Page 2 of 2

EXHIBIT 1